GEOTECTONIC EVOLUTION OF THE LATE PALEOZOIC MARITIMES BASIN

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GEOTECTONIC EVOLUTION OF THE LATE PALEOZOIC MARITIMES BASIN

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ABSTRACT

The late Middle Devonian to Early Permian Maritimes Basin of eastern Canada underlies an area of about 150 000 km^2. The basin is underlain by six major late Precambrian to mid-Paleozoic crystalline terranes or composite terranes that are bound by mainly steeply dipping, northeast-trending faults with complex Paleozoic histories.

The Maritimes Basin displays a two-phase (early and late) development. During the early phase (Late Devonian-Early Carboniferous), the basin evolved as a series of independent wedge-shaped, rhombic, or elongate subbasins separated by crystalline basement massifs. The subbasins are bound by regional northeast- to east-trending steeply dipping wrench or normal faults. In the late phase (Late Carboniferous-Early Permian) the multiple subbasins and intervening massifs subsided and the Maritimes Basin assumed a broad sag basin morphology.

The individual subbasins are characterized by basal, thick, marginal, alluvial-fan complexes and axial fluvial/lacustrine sequences. The basal rocks are overlain by Early Carboniferous (Viséan) marine limestone, anhydrite, and locally thick salt diapirs. The late phase deposits overlie the marine beds and are mostly widespread, relatively thin, fluviatile strata. Both the early and late sedimentary deposits locally contain thin tholeiitic and alkaline volcanic flows with chemical signatures consistent with an intraplate continental setting.

The sedimentary record in the basin is broken by many local unconformities, particularly along the margins of the subbasins. A regional diachronous unconformity of Late Mississippian to Early Pennsylvanian age marks the tectonic break between the early and late basin development.

Faults that were active in the early phase of the basin development are steep, northeast-trending structures. Folds that lie inclined to these faults suggest that many of the faults had Carboniferous oblique or dextral transcurrent displacement. Push-up blocks and recumbent cleavage folds are associated with later wrench and thrust faults.

By comparing the Maritimes Basin with ancient and modern basins in known strike-slip and rift environments it is concluded that the Maritimes Basin and its component subbasins evolved in a regional strike-slip fault zone.

RÉSUMÉ

Dans l'est du Canada, le bassin des Maritimes, qui s'est formé entre le dévonien moyen et le permien inférieur, s'étend sur une superficie d'environ 150 000 km^2. Ce bassin repose sur six importantes formations géologiques cristallines ou composites, datant de la fin de l'époque précambrienne au paléozoïque moyen et entourées par des failles fortement inclinées sur des axes nord-est. Ces failles, de formation complexe, datent du paléozoïque.

La formation du bassin des Maritimes s'est déroulée en deux étapes (antérieure et récente). Au cours de l'étape antérieure (dévonien supérieur-carbonifère inférieur), le bassin était constitué d'une série de bassins secondaires indépendants de forme rhombodéïque ou allongée, ou en biseau, séparés par des massifs cristallins. Les bassins secondaires sont limités par des failles de décrochement ou des failles normales régionales fortement inclinées à direction nord-est ou est. Au cours de l'étape récente (fin du carbonifère-début du permien), les bassins multiples et les massifs intercalés se sont affaissés et le bassin des Maritimes a pris sa forme large et abaissée.

Les bassins secondaires se distinguent par leurs ensembles de cônes de déjection de fond, épais et frontaux, et leur succession dans un axe fluvial, puis lacustre. Les roches de fond sont recouvertes de calcaire marin du carbonifère inférieur (viséen), d'anhydrite et, localement, par des diapirs de sel épais. Les dépôts de l'étape récente recouvrent les sédiments marins. Ils forment, en grande partie, des couches relativement minces et fluviatiles. Tant les sédiments de l'étape antérieure ainsi que ceux de l'étape récente contiennent, à certains endroits, des coulées de lave tholéiitique ou alkaline dont la composition chimique correspond à celle d'un milieu continental intraplaque.

Le relevé des sédiments du bassin indique de nombreuses discordances locales, plus particulièrement le long des limites des bassins secondaires. Une discordance régionale diachrone, du mississipien supérieur au pennsylvanien inférieur, marque la rupture tectonique survenue entre l'étape antérieure et l'étape récente de formation du bassin.

Les failles qui étaient actives lors de l'étape antérieure sont fortement inclinées et sur un axe nord-est. Les plis qui s'appuient sur ces failles laissent croire que de nombreuses failles sont issues de déplacements horizontaux, dextres ou obliques, survenus pendant le carbonifère. Les blocs poussés et les plis anticlinaux fracturés sont associés aux failles de décrochement et aux failles chevauchantes ultérieures.

La comparaison du bassin des Maritimes avec des bassins anciens et modernes se trouvant dans des zones connues de déplacements horizontaux et de haut-fond permet de conclure que le bassin des Maritimes et ses bassins secondaires se sont formés dans une zone régionale de failles de décrochement horizontal.

GEOTECTONIC EVOLUTION OF THE LATE PALEOZOIC MARITIMES BASIN

INTRODUCTION

The Maritimes Basin as defined by Williams (1974) is the largest post-Acadian intermontane basin in the Appalachian orogen (Figures 1 and 2). On land, the basin underlies parts of all four Canadian Atlantic Provinces, but most of the structure lies off shore beneath the Gulf of St. Lawrence and the continental shelf. The basin is underlain by deformed and metamorphosed sedimentary and volcanic rocks and a spectrum of plutonic rocks ranging from late Precambrian to Middle Devonian in age. The basin straddles all the major tectonostratigraphic zones or terranes in the northern Appalachians (Dewey 1969; Bird and Dewey 1970; Williams 1979; Kennedy 1979; Williams and Hatcher 1982; Keppie et al. 1985).

The stratigraphic section in the Maritimes Basin is mainly composed of a thick sequence of Middle Devonian to Permian continental red beds (Howie and Barss 1974). In the Early Carboniferous (Viséan), the southern and northeastern parts of the basin were transgressed by the Windsor sea, which laid down limestones, anhydrites and locally thick evaporites (Schenk 1969; McCutcheon 1981). Felsic and mafic volcanic rocks occur locally throughout the stratigraphic section (Dostal et al. 1983; Fyffe and Barr 1986).

The Maritimes Basin is not a simple symmetrical sag or depression. It is a complex series of mostly northeast-trending elongate intrabasinal uplifts or basement massifs bounding adjacent subbasins. The subbasins, containing Early Carboniferous deposits, are typically deep and elongate troughs parallel to the northeast grain of the Appalachian orogen. In contrast, the Late Carboniferous strata form a thin blanket covering most of the Early Carboniferous rocks and the basement massifs (Gussow 1953; Bradley 1982).

The Late Devonian and Early Carboniferous rocks of the Maritimes Basin are, in general, more highly deformed than the Pennsylvanian-Permian beds (Ruitenberg and McCutcheon 1982). The older strata show intense brittle deformation and steep dips adjacent to regional faults. The stratigraphic section is marked by numerous local unconformities or disconformities (Keppie 1985) that are largely related to tectonic movements in adjacent basement blocks. The entire basin displays evidence of Hercynian tectogenesis and nearly everywhere late Westphalian to Permian rocks lie with angular unconformity on earlier basin strata and crystalline basement (Ruitenberg and McCutcheon 1982; Keppie 1985).

The evolution of the Maritimes Basin has been attributed to a period of "relaxation" and block-faulting during the waning stage of the Acadian orogeny (Howie and Barss 1974, 1975), or similarly, as the result of a Late Paleozoic failed rift (Fyffe and Barr 1986). In contrast, Bradley (1982) feels that the basin evolved as a pull-apart along a wide plate boundary zone of dominantly right-lateral strike-slip. It is agreed by most writers that regional faults have played a significant and controlling role in the development of the Maritimes Basin. Nearly all the regional faults are steep. Some geologists argue that they are dominantly strike-slip (Belt 1968; Webb 1969; Arthaud and Matte 1977); and others argue that they are mainly dip-slip (Howie and Barss 1974, 1975; Ruitenberg and McCutcheon 1982).

The purposes of this paper are: (1) to review the stratigraphy and structural features of the Maritimes Basin; (2) to examine the geotectonic setting of the basin in light of recent ideas of accreted terranes, oblique collision, and long-lived strike-slip or transform faults in the Appalachians (Williams and Hatcher 1982; Keppie 1985; Gates et al. 1986), Caledonides (Leeder 1982; Bluck 1980; Reading 1982), and Hercynides (Badham 1982; Lefort and van der Voo 1981; Ziegler 1984); (3) to compare the Maritimes Basin with known Mesozoic-Cenozoic rift basins that have resulted from the break up of Pangea; and (4) to draw comparisons with known Tertiary pull-apart basins in California and elsewhere.

It is herein argued that the Maritimes Basin evolved in a strike-slip fault zone and consequently, Bradley's (1982) thesis is defensible - that the Late Paleozoic basins in the northern Appalchians are essentially pull-aparts.

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THE MARITIMES BASIN

The name Maritimes Basin, as used here, is in the sense of Williams (1974). He described the Maritimes Basin as the largest intermontane basin in the Appalachian Mountain system, having an area of 148 000 km^2 of which about 70 per cent is offshore in the Gulf of St. Lawrence and beneath the continental shelf (Figures 1 and 2). The name is purely descriptive; nothing is implied with respect to the origin of the basin. The name Maritimes Basin is prefered to that of Fundy Basin (Belt 1968), Fundy Epieugeosyncline (Kelley 1970), or Fundy Geosyncline (Poole 1967). The name Fundy Basin is too easily confused with the modern Bay of Fundy. The names Fundy Epieugeosyncline and Fundy Geosyncline are geotectonically outdated and should be abandoned.

The Maritimes Basin contains a sequence of mainly continental red beds that range in age from late Middle Devonian to Early Permian (Howie and Barss 1974, 1975; Williams 1974). The basin is underlain by Proterozoic to Middle Devonian rocks that have been subdivided into a number of tectonostratigraphic zones or terranes. To gain an appreciation of the tectonic evolution of the Maritimes Basin it is necessary to understand the history of the basement rocks and particularly to be aware of fundamental or terrane boundary faults.

GEOTECTONIC SETTING

Early Paleozoic Tectonic Terranes: Wilson (1966), Dewey (1969), and Bird and Dewey (1970) described the Appalachian-Caledonian orogen as the result of the opening and closing of a proto-Atlantic (Iapetus) ocean in late Precambrian to Middle Devonian time. Dewey divided the orogen into three tectonostratigraphic zones (Figure 3). The northwestern zone he designated orthotectonic zone A which comprises late Precambrian to Ordovician age miogeoclinal and continental rise deposits lying upon and adjacent to Grenville age basement. The southeastern zone, orthotectonic zone C, also comprises a late Precambrian to Lower Ordovician platformal and continental rise sequence with local deeper flysch basins (e.g., Welsh Basin). The medial or axial zone, Dewey (1969) called ensimatic paratectonic zone B. It contains early Paleozoic marine sedimentary rocks, island arc volcanics, and associated trench complexes that are believed to have been deposited on oceanic crust.

Kennedy (1979) expanded the three-fold division of the Appalachian-Caledonian orogen advanced by Dewey. Kennedy's classification into a northwestern marginal zone, a southeastern marginal zone and an axial zone is shown in Figure 2. The legend of Figure 2 provides a brief description of the various subzones within each zone.

Williams (1978) divided the northeastern Appalachians into five zones (Figure 4). The zones are from northwest to southeast: the Humber Zone (representing the ancient continental margin of eastern North America), the Dunnage Zone (containing vestiges of the Iapetus ocean), the Gander Zone (representing the eastern continental margin of the Iapetus), and the Avalon Zone and Meguma Zone (representing possible European and African elements). The reader is encouraged to examine the legend of Figure 4 to more fully understand the geotectonic significance of the five-fold division and also to appreciate the wide variety of rock types underlying the Maritimes Basin. The onland distribution of the Maritimes Basin is designated by the letter "C".

Williams and Hatcher (1982) reinterpreted the five-fold division of Williams (1978) and considered the zones to represent suspect terranes or composite terranes (Figure 5). Keppie (1985) further subdivided the Appalachian terranes of Williams and Hatcher (1982) and described the terranes as being bound by faults or melanges representing sutures, now largely cryptic, with complex structural histories often involving transcurrent motions. The major faults are, in part, northeast-trending Appalachian-Caledonian structures and, in part, east-trending Variscan structures (Figure 2).

Trans-orogenic Faults: The Maritimes Basin lies at the geographic intersection of the Appalachian-Caledonian orogen and the Hercynian orogen (cf. Figures 6 and 7), and consequently the basin shows evidence of being influenced by both orogenic trends (Lefort and van der Voo 1981). Most of the faults in the Maritimes are steep and follow the northeast trend of the Appalachian-Caledonian orogen (Belt 1968; Webb 1969). Some of these faults are regionally significant; Keppie (1985) considered the northeast-trending Norumbega-Fredericton Fault and the Lubec-Belleisle Fault, among others, as terrane boundary structures. The northeast-trending fault which has been assigned the greatest global significance in the Cabot Fault of Newfoundland (Figure 2). It is believed by many to be largely sinistral (Haszeldine 1984; Morris 1976; Lefort and van der Voo 1981; Ziegler 1984) and to be related to the Norumbega-Fredericton Fault in the New England Appalachians and the Great Glen Fault of northern Scotland (Phillips et al. 1969; Figure 8). Most of the displacement on the Cabot Fault system is thought to be mid-Devonian or earlier (Morris 1976). However, later displacements on this and parallel subsidiary faults have obviously had a controlling influence on the northeast-trending trough of Carboniferous sediments in Newfoundland (Figures 2 and 9).

The Cobequid-Chedabucto Fault (Figure 2) of Nova Scotia has an east-west trend and is probably related to Hercynian-Alleghenian tectogenesis (Mosher and Rast 1984). Marine geophysical data synthesized by Lefort and van der Voo (1981) has demonstrated that the Cobequid-Chedabucto Fault zone crosses the southern Grand Banks and probably joins a similar fracture zone on the Galicia Bank off western Iberia. They have shown that four major Carboniferous east-west fracture zones can be traced across the Atlantic from eastern North America to western Europe and northwestern Africa (Figure 10). Movement on these faults is dextral and in the Lefort and van der Voo thesis it is argued that faulting has resulted from the indention of northwestern Africa into northeastern North America (Figure 11, compare with Figure 10 for geographic details). In contast to Lefort and van der Voo (1981), Arthaud and Matte (1977) considered the late Paleozoic east-west dextral faults to result from the counterclockwise rotation of Gondwana with respect to Laurasia. Badham (1982) explained the dextral faulting as being related to the accretion of microplates in an oblique collision zone. Regardless of the differences in details among the various plate tectonic models to explain the dextral faults, the Cobequid-Chedabucto Fault is a demonstrable terrane boundary (Williams and Hatcher 1982; Keppie 1985), and it has played an important role in the location and morphology of the Maritimes Basin.

SEDIMENTARY RECORD

The Maritimes Basin is a complex structure comprising a series of elongate northeast-trending troughs or subbasins separated, or partially separated, from one another by intervening basement uplands. The names of the subbasins and uplands are taken from Kelley (1967) and are shown on Figure 12. Regionally, the Maritimes Basin displays broad similarities in stratigraphy from subbasin to subbasin, with rocks ranging in age from Middle Devonian to Early Permian (Figure 13). Locally, stratigraphic sections in individual subbasins show considerable variations that cannot be extrapolated basin-wide. The regional stratigraphy and some of the more important local features are summarized below.

Horton Group: The Horton Group as used here defines the base of the stratigraphic section in the Maritimes Basin (Howie and Barss 1974) and includes a wide spectrum of formations not included in the original definition by Bell (1929). A summary of the formations correlative with the Horton Group are shown in Figure 14.

The Horton Group lies with angular unconformity on a basement of Precambrian to Middle Devonian rocks (see above under Geotectonic Setting). The group includes rocks ranging in age from Middle Devonian to Early Carboniferous (Early Viséan). The distribution and thickness of the Horton is shown in Figure 15. Wells drilled in northern Prince Edward Island and northeastern New Brunswick since 1974 show that there are no Horton Group rocks in these areas, in contrast to what is shown in Figure 15. There may not be any Horton or Windsor Group rocks in the northern part of the Gulf of St. Lawrence (Figure 15; see Bradley 1982). The Horton group locally shows very rapid changes in thickness from a few metres to greater than 3000 m. The interpreted thickness in the Magdalen Subbasin is greater than 4000 m. The Horton has been intersected in oil and gas exploration wells on the continental shelf east and southeast of Newfoundland (Figure 16).

The Horton Group comprises mainly red poorly sorted polymictic conglomerates, sandstones, mudstones, and shales typical of alluvial fan and associated braided stream deposits. Individual formations show rapid facies changes. For example, in the Moncton Subbasin coarse-grained beds of the Memramcook and Moncton formations adjacent to the Caledonian upland commonly grade laterally within 1 or 2 km into mudstone and shale in the adjacent basin (Pickerill and Carter 1980; Pickerill et al. 1985). The Horton Group also contains lacustrine siltstones and shales and rare evaporites in the Albert Formation of New Brunswick (Greiner 1962; Pickerill et al. 1985).

Windsor Group: The Windsor Group contains the only marine rocks in the Maritimes Basin. Kelley (1967) defined the Windsor as "partly or wholly a marine sequence of strata that conformably to unconformably overlies the Horton Group and overlaps pre-Carboniferous rocks". The Windsor strata are middle to late Viséan in age (Utting 1980; McCutcheon 1981).

The distribution and thickness of the Windsor Group is shown in Figure 17. The elliptical closures of isopachs in the Cumberland and Magdalen subbasins is the result of salt domes and pillars (Howie and Barss 1974, 1975). A few explanatory notes are warranted with respect to Figure 17. Mapping in New Brunswick has shown that there are no Windsor rocks in the Plaster Rock area of north-central New Brunswick (St. Peter 1979). Hopewell Group strata that Howie and Barss (1974) include in the Windsor of southeastern New Brunswick are excluded, and therefore considered part of the overlying Canso Group by McCutcheon (1981). An exploration well, Imperial Porthill No. 1, drilled in northern Prince Edward Island, shows that there is no Windsor in this area and it seems likely there is no Windsor between northern Prince Edward Island and Anticosti Island, i.e., north of the Magdalen Subbasin (Bradley 1982). The Windsor has, however, been intersected by drilling on the continental shelf (Figure 16) south of Newfoundland (Howie and Barss 1974, 1975).

The Windsor Group was divided by Bell (1929) into five subzones which have been interpreted as transgressive and regressive cycles. The cycles comprise algal and brachiopod-bearing patch reefs, algal laminated carbonates, gypsum, anhydrite, salt, local potash beds, red mudstones and coarse-grained clastic rocks. The clastic rocks occur as facies on the upland side and adjacent to the transgressive margins of the Windsor sea. The Windsor locally overlaps the underlying Horton and lies unconformably on basement rocks (McCutcheon 1981; Howie and Barss 1974, 1975).

Canso-Riversdale Group: The Canso Group and Riversdale Group comprise several distinct sequences given local formation names as shown in Figure 18. The groups are diachronous (Kelley 1967) and range in age from Late Viséan to Westphalian A. The isopach map (Figure 19) shows that the Canso-Riversdale section is generally quite thin. However, there may be up to 3000 m of strata in the George Bay area (Figures 16 and 19) between the Nova Scotia mainland and Cape Breton Island.

In Nova Scotia, the Canso Group is mostly red to grey shale with minor sandstone and nonmarine limestone. In New Brunswick, equivalent rocks of the Hopewell Group contain abundant red to grey alluvial-fan conglomerate in the upper part of the section. The Bonaventure Formation of northern New Brunswick and Gaspé is predominantly red debris-flow conglomerates. The Canso rocks of Newfoundland comprise fine-grained red beds of the upper Codroy Group and coarse red beds of the overlying Barachois Group (Howie and Barss 1974).

The Riversdale Group consists of red to grey sandstone, siltstone and shale. The Riversdale strata in the Minas Subbasin (Figure 12) are mainly grey shale and siltstone. In the Moncton Subbasin and in parts of the New Brunswick Platform (Figure 12), the Riversdale Group consists of quartz-pebble conglomerates and quartzose arenites of the Boss Point Formation (Howie and Barss 1974, 1975; Ball et al. 1981). The Riversdale strata were largely deposited in a fluvial environment; coaly shale and local coal seams are common.

Cumberland-Pictou Groups: The relationship between the Cumberland and Pictou groups and correlative rocks throughout the Atlantic Provinces is shown in Figure 20. The Cumberland and Pictou strata are, in part, contemporaneous, and consequently the groups are combined on the isopach map in Figure 21.

The Cumberland Group is mainly restricted to the Cumberland Subbasin (Figure 12) where it is up to 3300 m in thickness (Figure 21). The overlying Pictou Group is the most widespread sequence of rocks in the Atlantic Provinces (Figure 21, cf. Figures 38, 39, and 40). It overlies and oversteps earlier Devono-Carboniferous groups (in most places, unconformably) and in many places it lies upon crystalline basement. The Pictou Group is believed to be thickest in the eastern Prince Edward Island area where possibly 3600 m of strata occur.

The Cumberland Group comprises continental red and grey conglomerate, sandstone, shale and coal. Floral assemblages give a late Westphalian A to early Westphalian B age for these rocks. The very rapid deposition of the Cumberland sediments is indicated by the local preservation of 9 m upright trees.

The Pictou Group contains fluviatile red and grey sandstone, arkosic grit, mudstone, red and grey shale (Poll 1970), and in the Stellarton Gap (Figure 12) there are beds of oil shale (Macauley and Ball 1984) and mineable coal seams (Howie and Barss 1974). Coal is common in the correlative rocks of the Inverness Formation and Morien Group of Cape Breton Island. Strata at or near the base of the Pictou yield Westphalian B or C ages. The youngest rocks in the group on Prince Edward Island have provided Early Permian spores.

BASIN MORPHOLOGY

The geographic outline of the Maritimes Basin is shown in Figure 1. In detail, the basin is seen to comprise a number of subbasins that are separated or, in part, separated by intervening basement uplands (Kelley 1967). The location and names of the main subbasins, uplands and platforms, as designated by Kelley (1967), are shown on Figure 12. The subbasins and uplands of Kelley (1967) are called basins and massifs by Bradley (1982). Compare Figures 12 and 22.

The main depocentres of Horton sedimentation are the Moncton Subbasin, Cumberland Subbasin, Minas Subbasin, Stellarton Subbasin, Mabou Subbasin, Magdalen Subbasin, St. George's Subbasin and White Bay Subbasin (Figures 12, 15, and 22). The subbasins are spatially distinct, contain abundant alluvial-fan deposits, and show very rapid increases in sediment thickness adjacent to upland blocks or massifs (Figures 15 and 23). The Moncton Subbasin in Horton time was wedge-shaped and was widest in the northeast (Figure 15). It has a shape analagous to the configuration depicted by Mann et al. (1983) for a modified pull-apart basin (Figure 61B) or the rotating fault wedge shown by Freund (1982; Figure 63a). The rhomboid-shaped Mabou Subbasin (Figures 15 and 22) is morphologically comparable to the pull-apart form of Mann et al. (1983) (Figure 61D) or the pull-apart rhomb graben model of Freund (1982; Figure 63b). The Magdalen Subbasin in Horton time had nearly the same rhomboidal shape as the Mabou Subbasin (Figure 15). The Cumberland, Minas, St. George's and White Bay subbasins are elongate troughs that are either conventional rift basins (Figures 84, 85, and 87) or basins showing extreme pull-apart development (Figures 62E).

During the Windsor marine transgression, the Cumberland and Magdalen subbasins were the primary centres of deposition and thick salt sequences accumulated there (Figure 17). Throughout Windsor time, the Cumberland Subbasin retained its rift-like graben shape. The Magdalen Subbasin became more rhomboidal when the southwest part of the basin in Prince Edward Island began to founder (cf. Figures 15 and 17).

The Canso and Riversdale groups form a blanket-like cover less than 1 200 m in thickness on the platformal areas of the Maritimes Basin (Figure 19). The thickest sections of Canso-Riversdale strata are in wedge-shaped depocentres in the northern part of the Cumberland Subbasin and the southern part of the Mabou Subbasin (Figures 19 and 22).

The Cumberland and Pictou rocks form a widespread but thin cover over parts of the New Brunswick Platform, Nova Scotia Platform, Cape Breton Island and Newfoundland (Figures 21 and 41). The main depocentres for the Cumberland-Pictou strata are in the Cumberland Subbasin, and the southern and northern parts of the Magdalen Subbasin. The depocentres are separated by a structural high trending east-northeast across the Magdalen Subbasin (Figure 21). Similar basin morphologies have been described by Mann et al. (1983) in the Miragoane Lakes Basin in Haiti (Figure 66A) and the Cariaco Basin of Venezuela (Figure 66B).

The Maritimes Basin contains a thick sequence of strata along its axis from the Cumberland Subbasin in the southwest to the White Bay Subbasin in the northeast (Figures 22, 23, and 24). It should be noted that Figure 24 is partly in error. The "thin cover" in the Magdalen Island area of the Gulf of St. Lawrence is not as Belt (1963) has shown. Seismic refraction surveys (Sheridan and Drake, 1968) indicate that in excess of 7 km of Carboniferous sediments underlie this area (Figure 23). The thick axial sediments are flanked by a thin cover of mostly Late Carboniferous and Early Permian deposits on the adjacent platforms (Figures 19, 21, 22, 23, and 24). The platformal deposits are in basins analagous to the "sag" basins of Great Britain (Leeder 1982; Figure 87).

The morphology and evolution of the Maritimes Basin have been summarized by Bradley (1982). He described the basin as the result of an initial "rift" stage and a subsequent thermal subsidence stage (Figure 25).

IGNEOUS ACTIVITY

The distribution of most of the Devono-Carboniferous volcanic rocks in the Maritimes Basin is shown in Figure 26 (Fyffe and Barr 1986), and Figure 27 (Dostal et al. 1983). Additional basaltic flows occur on the Magdalen Islands in the Gulf of St. Lawrence (Barr et al. 1985). Minor basalt flows are known in the Bonaventure Formation (Figure 18) of southern Gaspé (Howie and Barss 1974).

The volcanic rocks in New Brunswick can be divided into three age groups. The late Tournaisian to early Viséan rocks in the Gladwyn, Carlisle, Hoyt and Mount Pleasant areas (Figure 26) are tholeiitic basalts and andesites except in the Mount Pleasant area where there are abundant calc-alkalic rhyolites (Fyffe and Barr 1986). Late Viséan to Namurian rocks at Queenstown, Minto, Royal Road and Boiestown are alkali basalts and trachyandesites. Late Westphalian volcanics in the Minto area range from trachyte to peralkaline rhyolite.

The Devono-Carboniferous volcanic rocks of Nova Scotia (Figure 27) comprise the Middle Devonian tholeiitic basalts of the McAras Brook Formation, the Middle Devonian alkali basalts of the Ballantynes Cove area, the Middle Devonian and Carboniferous (poorly dated) tholeiitic basalts and rhyolites of the Fountain Lake Group, and the Upper Devonian to Lower Carboniferous tholeiitic basalts and rhyolites of the Fisset Brook Formation (Dostal et al. 1983).

The Mississippian Windsor Group basalts in the Magdalen Islands show both tholeiitic and alkalic chemistry (Barr et al. 1985).

All the Devono-Carboniferous volcanic rocks in New Brunswick (Figure 28), Nova Scotia (Figure 29), and the Magdalen Islands (Figure 30) show TiO_2 versus Zr discrimination diagrams consistent with an intraplate continental setting. Fyffe and Barr (1986) favoured a rift setting; Dostal et al. (1983, 1986) suggested that the Nova Scotia volcanics have evolved in a transpressive setting.

A chemical and radiometric classification of Acadian plutonic rocks in New Brunswick shows that the plutons form a chronologically uninterrupted suite ranging in age throughout the Devonian to Early Carboniferous (Fyffe et al. 1981). The bimodal character and evolutionary trend of the Acadian plutonic rocks rule out a direct relationship with a subduction origin; their origin is more likely the result of crustal thickening (Fyffe et al. 1981). This supports the view that compression or transpression was the dominant stress regime during Late Devonian and Carboniferous time.

SUMMARY OF STRUCTURAL FEATURES

A summary of the late Paleozoic tectonic events in the Northern Appalachians (Figure 31) is given by Arthaud and Matte (1977). In their model, Mississippian tectonics are dominated by rifting or wrench faulting, the latter continuing into the Permian when continental collision and associated thrust faulting occurred. A somewhat different interpretation has been advanced by Ruitenberg and McCutcheon (1982) for the Hercynian structural events affecting the Maritimes Basin (Figure 32). In the Ruitenberg and McCutcheon model, normal faulting is dominant, and wrench faulting has not played a significant role. Also they have documented folding in the late Tournaisian, Viséan, and late Westphalian. The late Westphalian folding is accompanied by thrust faulting.

Folds and Unconformities: In the Moncton Subbasin, the strata of the Horton Group, lying below the Hillsborough Formation (Figure 14), are folded into open to tight folds (Gussow 1953; Webb 1963; Ruitenberg and McCutcheon 1982). These folds have been mapped by Webb (1963) and are shown on Figures 33 and 34. In proximity to the Caledonia upland (Figure 12) and along the north side of the Moncton Subbasin, the folded Tournaisian Lower Horton rocks are unconformably overlain by the Viséan(?) Hillsborough Formation or the Viséan Windsor Group (Gussow 1953; Ruitenberg and McCutcheon 1982). A local unconformity in the upper part of the Horton Group is also reported in the Antigonish-Mabou Subbasin by Kelley (1967; Figure 12).

A period of late Tournaisian or early Viséan deformation is also recorded in the Deer Lake Subbasin of Newfoundland (Figure 22) where the mildly deformed Cansoan Deer Lake Group unconformably overlies the basement and the Tournaisian Anguille Group as shown in Figure 9 (Belt 1969; Hyde 1984).

The second major deformational event that affects the Maritimes Basin is diachronous. In the Moncton Subbasin, pre-Enragé Formation - that is pre-late Namurian - strata are deformed into open northeast-trending folds (Gussow 1953; Webb 1963). These folds are distinguished from the earlier folds by Webb (1963) and are shown in Figure 35. The Enragé Formation unconformably overlies earlier Carboniferous rocks and, in places, oversteps onto basement uplands. In Nova Scotia, the second deformational event is later. There, late Westphalian B strata of the Pictou Group mark the base of the unconformity (Keppie et al. 1985). Further details on local unconformities in the eastern part of the Cumberland and Stellarton subbasins is given by Fralick and Schenk (1981).

The major Hercynian folds in New Brunswick are documented by Ruitenberg and McCutcheon (1982; Figure 36). A compilation of Hercynian or Variscan fold structures in the Maritimes is shown by Arthaud and Matte (1977; as seen in Figure 37) and in more detail by Webb (1969; as per Figures 42 and 43). The relationship of these folds to major faults in the Maritimes Basin is discussed in the next chapter.

Faults: There is irrefutable evidence that steeply dipping strike-slip faults and normal faults cut the Devono-Carboniferous strata of the Maritimes Basin. There is similarly evidence of numerous faults with substantial thrust movement. The literature describing late Acadian and Hercynian faults and their role in the evolution and subsequent deformation of the Maritimes Basin is too voluminous to summarize here. The major faults and the relevant evidence of their sense of movement is the subject of the next chapter.

LATE PALEOZOIC STRIKE-SLIP FAULTS IN THE NORTHERN APPALACHIANS

SIGNIFICANT FAULTS IN THE MARITIMES BASIN

As described above under "Geotectonic Setting", the Maritimes Basin lies at the intersection of the early to middle Paleozoic Appalachian-Caledonian fold belt and the late Paleozoic Hercynian fold belt (Figures 6 and 7). Both the basement terranes and the Devono-Carboniferous cover rocks in the Maritimes are transected by faults that show northeasterly Appalachian trends (Figure 38) or east-west Hercynian trends (Figures 39 and 40). Those faults or fault zones that have had a controlling influence on the inception, sedimentary history or subsequent tectogenesis of the Maritimes Basin are described below.

Fredericton-Norumbega Fault: The Fredericton Fault of New Brunswick and/or its extension, the Norumbega Fault of New England is depicted on Figures 22, 26, 36, 38, 42, and 43. This fault can be traced with confidence for over 600 km from Massachusetts to New Brunswick. It defines a fundamental terrane boundary that is not overstepped until Carboniferous time (Keppie 1985).

Webb (1969) recorded the presence of steeply dipping Carboniferous rocks near the fault southwest of Fredericton. Ruitenberg and McCutcheon (1982) descibed the Fredericton-Norumbega Fault as a major dextral strike-slip fault that shows substantial post-Acadian offset and rotation of Acadian structural trends (Figure 36). Ball *et al*. (1981) cited evidence that the Fredericton Fault has post-Stephanian dip-slip movement with the southeast side moving down. The subhorizontal Namurian age Royal Road basalt exposed at the surface on the north side of the Fault was intersected at 737 m in the Killarney No. 3 drill hole on the south side of the fault. The presence of the basalt in the drill hole immediately southeast of its surface exposure indicates that strike-slip movement was limited in post-Namurian time.

Lubec-Belleisle Fault: The Lubec-Belleisle Fault is shown on Figures 2, 3, 22, 24, 26, 33, 35, 36, 42, 43, and 46. It is exposed from southern coastal Maine through southern New Brunswick. It is believed to define the northern boundary of the Magdalen Subbasin in the Gulf of St. Lawrence (Figure 22, after Bradley 1982).

Gussow (1953) believed the Belleisle Fault of southern New Brunswick to be a northwest-dipping thrust and that in the Belleisle Bay area, crystalline basement rocks overthrust upper Horton Group (Moncton Formation) conglomerate. Gussow's interpretation has not gained wide acceptance.

In 1963, Webb described the Belleisle Fault as a large dextral strike-slip fault that defines the boundary between the Moncton Subbasin to the southeast and the New Brunswick Platform to the northwest (Figure 26). Webb (1963) considered the Lubec-Belleisle Fault to have a considerable pre-Carboniferous history.

Ruitenberg *et al*. (1979) wrote that the geometry of folds in rocks of Precambrian to Upper Silurian age near the fault are consistent with dextral offset. Similar Silurian strata on either side of the fault do not support major post-Acadian offset (Ruitenberg *et al*. 1979).

Ball *et al*. (1981) described overlapping stratigraphic units and unconformities along the Kingston-Indian Mountain Uplift (Figure 33). From this, they argued that the Belleisle Fault shows two periods of normal and two periods of reverse movement from Viséan to post-Stephanian time.

The Belleisle Fault was certainly active during Horton Group time. Horton Group alluvial-fan conglomerates occur on the south side of the fault in the area north of the Havelock Syncline (my unpublished data; see also Figure 35). The fault is overstepped by Riversdalian age rocks (Belt 1968).

Peekaboo-Berry Mills Fault: The Peekaboo-Berry Mills Fault occurs in the Moncton Subbasin of southern New Brunswick and is shown on Figures 33, 34, 35, 36, 43, and 47. Ruitenberg and McCutcheon (1982) called it the Kennebecasis Fault (Figure 36). Webb (1969) assigned the fault No. 21 (Figure 43). Note that the cross section A-A' in Figure 34 is shown in Figure 47.

The Peekaboo-Berry Mills Fault can be followed for 120 km across southern New Brunswick (Gussow 1953). It defines the boundary between the Kingston basement block and Hopewell Group alluvial-fan conglomerates (Pickerill et al. 1985) in the Bloomfield area (Figure 33). In this area, tight folds in the Hopewell rocks terminate against the fault and a narrow sliver of Albert Formation is sheared against the basement (my unpublished data). The fault is steeply-dipping in surface exposures and is not indicative of a thrust as proposed by Gussow (1953).

In the Indian Mountain area (Figure 34), a water well drilled to a depth of 225 m on the south side of the fault remained in Pictou Group strata (Gussow 1953). The presence of Moncton Formation (Horton Group) rocks on the north side of the fault in this area implies that the fault moved down on the south side (Figure 47). The Pennsylvanian Pictou Group rocks near the fault in the northeasternmost part of Figure 34 are subvertical (my unpublished data).

Webb (1963, 1969) considered the Peekaboo-Berry Mills Fault a dextral strike-slip fault with an offset of perhaps 5 to 40 km. He believed that the Kingston basement rocks (Figure 33) moved northeast into the Moncton Subbasin. He also stated (but did not demonstrate) that the Peekaboo-Berry Mills Fault dextrally displaces Albert Formation isopachs.

Lutz Mountain Fault: The Lutz Mountain Fault is shown on Figures 33, 34, 35, 43, and 47. On Figure 43, Webb (1969) assigned the fault No. 45. Section line A-A' on Figure 34 is shown on Figure 47.

Gussow (1953) described this fault as a subsidiary feature marked by discordant structures on either side. Granite and diorite of Devonian or older age on the south side are in reverse fault or thrust contact with upper Horton Group (Moncton Formation) red beds to the north (Figure 34). The Horton Group rocks, lying on the granite sliver to the south, are folded into north-northeast-trending folds that trend oblique to the fault trace (my unpublished data) and indicate a dextral strike-slip displacement (Figure 34). The Lutz Mountain Fault is thought to be unconformably overlain by the Pennsylvanian Pictou Group.

Clover Hill Fault: The Clover Hill Fault is displayed on Figures 22, 24, 33, 35, 36, and 43. On Figure 22 it is labelled "CHF" and on Figure 43 it is assigned No. 22.

Gussow (1953) documented discordant structures across the fault. Locally there are contorted rocks and slickensides but no evidence of motion is given (Gussow 1953). The late Mississippian or early Pennsylvanian Hopewell Group rocks on the south side are in reverse fault or thrust contact with basement granite and Horton Group red beds on the north side (Gussow 1953; Webb 1963, 1969; Belt 1968; Ruitenberg and McCutcheon 1982).

Belt (1968) believed that the Clover Hill Fault was responsible for the formation of alluvial-fan red beds of the Horton Group which lie to the north of the fault. Webb (1969) assigned 13 km of dextral displacement to the Clover Hill Fault on the tenuous basis that basement rocks in the southwest part of the Moncton Subbasin have moved northeast with respect to the adjacent Hopewell Group. The basement rocks in this area may have moved up on the northwest side of the fault, and if so, then lateral displacement is not needed to explain the geometry. It is not known whether the Pennsylvanian Boss Point Formation or Pictou Group are displaced by the Clover Hill Fault.

There are several faults northeast of the Clover Hill Fault that define the north boundary of the Caledonian upland or Arch (Figures 33 and 35). All these faults were active during Horton time and have given rise to Horton Group fanglomerates that grade basinward to the north into finer grained clastics (Pickerill et al. 1985; my unpublished data). The Viséan Windsor Group is nowhere greatly offset by these faults.

Harvey-Hopewell Fault: The Harvey-Hopewell Fault is depicted on Figures 22, 24, 36, 42, 43, and 47. On Figure 22, it is designated "HHF", on Figure 43 it is numbered 27, and on Figure 47 it is shown on section B-B'.

The fault can be traced for over 50 km along the south side of the Caledonian upland where it cuts Windsor, Hopewell and Riversdalian Boss Point strata (Gussow 1953; Webb 1963, 1969; Belt 1968; Ruitenberg and McCutcheon 1982). The Harvey-Hopewell Fault displays northwestward-thrusting, and at Albert, crystalline basement rocks override the Boss Point Formation. Surface exposures show that the fault dips 35° to 50° southeast (Gussow 1953).

Webb (1963, 1969) described a 15 km early Pennsylvanian left-lateral offset on a Hopewell Group alluvial fan that lies to the south of the fault. Webb (1963, 1969) ascribed the lateral displacement to north-south compression.

The presence of the Hopewell Group alluvial fan on the south side of the fault implies that the fault had a normal or oblique, down-to-the-south, component of movement before or during Hopewell Group time. The fault was subsequently reactivated and the alluvial fan rocks were thrust back over their northern source area.

Cobequid-Chedabucto Fault System: The Cobequid-Chedabucto Fault and various subsidiary parallel splays are shown on Figures 2, 3, 5, 22, 24, 36, 37, 39, 40, 42, 43 (localities 4, 5, and 31), 45, and 46.

The Cobequid-Chedabucto Fault defines a terrane boundary between the Meguma Terrane to the south and the Avalon Composite Terrane to the north (Figure 5). The oldest rocks that can be correlated across the fault are late Lower Devonian (Emsian) quartzites and siltstones (Ruitenberg and McCutcheon 1982).

The Cobequid-Chedabucto Fault (Minas Geofracture of Keppie, 1985) is one of the most significant faults in the Maritimes and it has played a controlling role in the location and subsequent sedimentary history of the Maritimes Basin. It has been traced east across the continental shelf by Haworth (1975) where it forms the magnetic and gravity "Collector Anomaly" (Figure 5). Lefort and van der Voo (1981) and Lefort and Haworth (1984) have correlated the Cobequid-Chedabucto fracture zone with an east-trending fracture zone on the Galicia Banks off western Portugal (Figures 13 and 45). Haworth (1975) provided seismic evidence that the north side of the fault has moved up.

Belt (1968) described the fault as a major dextral structure, and he cited ruptured pebbles and lineations as supporting evidence that the fault moved up slightly on the north side. The fault is seen to dip at 40° to 70° south toward the Minas Subbasin (Figure 22). Arthaud and Matte (1977) have recorded horizontal slickensides in basement mylonites in the Canso area.

Keppie *et al*. (1985) gave a synthesis of movements on the Cobequid-Chedabucto Fault. From Middle Devonian to Permian time, there was 370 km of dextral offset between southern New Brunswick and Cape Breton Island and about 475 km of offset between the Meguma Terrane and northern Nova Scotia terranes. The difference in offset was accommodated by shortening along thrusts and folds in southern coastal New Brunswick (see below under "Evidence of Thrusting").

Belt (1968) documented facies gradations of Cansoan, Riversdalian and Cumberlandian age that he believed were related to dip-slip movement on the Cobequid-Chedabucto Fault system. The coarse to fine facies gradations could just as well have developed by oblique slip movement related to the known regional dextral transcurrence on this system.

Hollow Fault: The northeast-trending Hollow Fault is shown on Figures 22, 42, and 43. It is denoted by No. 33 on Figure 43 (Webb 1969).

The Hollow Fault is poorly exposed on land and lies mostly offshore along the northwest coast of Cape Breton Island. The fault cuts upper Windsor Group rocks and is overlain by Cumberlandian age beds (Belt 1968). Coarse clastic facies of Windsor age reportedly lie adjacent to the fault (Belt 1968). It is believed by Belt (1968) that any wrench movement on the Hollow Fault had ceased during Windsor time. This has been challenged by Fralick and Schenk (1981) who demonstrated that deposition of the Stellarton Formation accompanied dextral movement on the Hollow Fault in Westphalian C time.

The Hollow Fault defines the northwest boundary of the rhombic Mabou Subbasin (Figure 22) which contains a very thick section of Horton strata (Figure 15).

Aspy Fault: The Aspy Fault trends parallel to the Hollow Fault and is depicted on Figures 2, 22, 24, and 42. On the later figure it is designated by No. 33.

The nature and magnitude of post-Acadian displacements on the Aspy Fault are not well documented in the readily available literature (Belt 1968; Webb 1969). Basement rocks along the fault are much deformed and Acadian intrusive rocks are offset. The fault cuts Horton Group Fisset Brook rocks and gives rise to facies-dependent alluvial Windsorian and Cansoan age beds. Displacements on the Windsor rocks are dextral in the northern part of Cape Breton Island and sinistral in the south part (Webb 1969). Belt (1968) stated that the Aspy Fault may have a large dextral strike-slip component.

St. George's Bay - Taylors Brook Fault System: The northeast-trending St. George's Bay - Taylors Brook Fault system of Newfoundland is shown on Figures 9, 22, 24, 44, 46, and 48. On Figure 44 the various splays of the system are numbered 116, 118 and 72.

The St. George's Bay Fault (Figure 9) of southwestern Newfoundland is marked by a sinuous shear zone several kilometres wide in basement rocks of the Miogeoclinal Terrane (Figure 5). The Codroy (Windsor Group) and Barachois Group (Figure 18) on the west side of the fault are only a few tens or hundreds of metres thick (Belt 1969). In the "graben" or trough to the east of the fault, the Codroy section is nearly 1.5 km thick and the Barachois Group is greater than 1.5 km thick.

The Taylors Brook Fault (Figure 9), like the St. George's Bay Fault, cuts the Tournaisian Anguille Group (Figure 14), and is overstepped by Cansoan strata of the Deer Lake Group. The Taylors Brook Fault is locally seen to dip at 60° southeast into the White Bay Subbasin (Figure 22).

The Birchy Ridge Fault (Figures 9 and 14) is parallel to and lies to the southeast of the the Taylors Brook Fault. The Anguille Group rocks to the southeast of the Birchy Ridge Fault are highly folded and deformed. The fault is marked in its southern extension by an elongate sliver of granite basement suggesting to Belt (1969) that wrench faulting occurred in Mississippian time. The Birchy Ridge Fault is overlapped in the south by the late Viséan or Namurian (Hyde 1984) Deer Lake Group.

Long Range - Grand Lake - Hampden Fault System: The Long Range - Grand Lake - Hampden Fault system is also known as the Cabot Fault system. The northeast-trending faults forming this major regional fracture are shown on Figures 1, 2, 3, 4, 8, 9, 22, 24, 37, 38, 44, and 46. In Figure 4, the contact between the Humber Zone and Dunnage Zone is more or less coincident with these faults. In Figure 44, the faults are designated by numbers 32 and 75.

The Long Range, Grand Lake, and Hampden faults define the southeast boundary of the St. George's, Deer Lake, and White Bay subbasins (Figure 22). The St. George's Subbasin along the Long Range Fault (Figure 9) is characterized by abundant late Mississippian and Pennsylvanian proximal fanglomerates of the Codroy (Windsor) and Barachois Groups (Belt 1968, 1969; Webb 1969). There are also locally coarse proximal clastic rocks of the Hortonian Anguille Group along the Long Range Fault (Webb 1969). This fault is seen to dip at 35° to 80° northwest toward the St. Geroge's Subbasin. Carboniferous dextral strike-slip displacement is interpreted from en echelon fractures, shears, slickensides and drag folds (Belt 1968, 1969; Webb 1969).

The Grand Lake Fault on the southeast side of the Deer Lake Subbasin is followed along its northwest side by fanglomerates of the Viséan to Namurian Deer Lake Group and Namurian(?) lower Barachois Group. The fault is unconformably overlapped on the northeast end by Westphalian A (Hyde 1984) strata of the Howley Formation.

The Hampden Fault forms the southeast shore of White Bay (Figure 9). Anguille Group rocks on the northwest side of this fault are tightly folded and complexly deformed (Belt 1969). There are no known fanglomerates associated with the Hampden Fault. No Late Carboniferous strata overstep the fault, and therefore, the history of its movement is unknown. Phillips et al. (1969) speculated the fault moved in pre-Horton, post-Horton and in post-early Pennsylvanian time.

Sheridan and Drake (1968) provided seismic-refraction and magnetic profiles across the Cabot Strait between Newfoundland and Cape Breton Island (see their figure 7 for details). From their sections, it is indicated that the Long Range - Grand Lake - Hampden Fault system probably joins the Hollow Fault that lies offshore of northwestern Cape Breton (Figures 42 and 43). The fault system, interpreted in this way, forms the southeast boundary of a very deep "Carboniferous" trough (Figures 15, 17, and 21). Howie and Barss (1975) used the Sheridan and Drake (1968) data to construct the sections in Figure 23, that show the Long Range and Hollow Fault correlation on section D-B-E.

FOLDING ASSOCIATED WITH THE FAULTS

Two periods of folding have been documented in the Devono-Carboniferous rocks of the Maritimes Basin (Gussow 1953; Webb 1963, 1969; Ruitenberg and McCutcheon 1982). The earlier folding occurred in late Tournaisian or early Viséan time (Ruitenberg and McCutcheon 1982; see Figure 32) and coincides with local unconformities that have been recognized in the Moncton Subbasin (Gussow 1953; Ruitenberg and McCutcheon 1982), the Mabou Subbasin (Kelley 1967), the St. George's Subbasin (Webb 1969; Belt 1969), and in the Deer Lake Subbasin (Belt 1969; Hyde 1984). The early folds typically lie oblique to the regional northeast-trending faults (Figures 33, 34, 36, and 43). The folds have been interpreted by Webb (1963) to have formed synchronously with the northeast strike-slip faults by east-west-directed compression. Comparable fold and fault geometries have been documented by Howell et al. (1980) in wrench tectonic settings in basins of southern California (Figure 68). Fold axes lying oblique to strike-slip faults are characteristic of transpressional settings (Reading 1982; see also Figure 73). The earlier period folds in the Moncton Subbasin are typically open except in proximity to faults where they are tight and locally overturned (Gussow 1953; my unpublished data).

The second or later period of folding occurred in the Namurian or early Westphalian. The folds are typically open northeast-trending structures that, in New Brunswick, more or less lie parallel to the northeast-trending faults (Webb 1963; see also Figure 35). Webb (1969) argued from this, that this phase of folding was related to a period of northwest-southeast-directed compression and associated thrust faulting. This period of compression explains the late Namurian to early Westphalian unconformity documented throughout the Maritimes Basin (see above under "Summary of Structural Features"). The compressional deformation continued into the late Pennsylvanian. This is shown by post-Hopewell and post-Boss Point (Westphalian A) thrusting on the Clover Hill and Harvey-Hopewell faults (Ruitenberg and McCutcheon 1982).

The late period of folding in Nova Scotia is characterized by folds that lie oblique to the Cobequid-Chedabucto Fault (Figures 42 and 43). The fold orientations are consistent with Pennsylvanian dextral offset on that fault system. Late folds lying oblique to northeast-trending faults in Cape Breton Island are shown on Figure 43. Analagous fault and fold patterns are also documented in the Deer Lake Basin of Newfoundland (Hyde 1984).

EVIDENCE OF THRUSTING

The most significant Carboniferous thrust faulting in the Maritimes is in southern New Brunswick (Figures 36 and 37) along the north shore of the Bay of Fundy and within the southern part of the Caledonia upland. The faulting there is called the Variscan Front by Rast and Grant (1973) and the Fundy Cataclastic Zone by Ruitenberg et al. (1973). The thrust front east of Saint John is characterized by polydeformed (F_1, F_2, and F_3 folded) Mississippian(?) Mispec Group rocks and other Avalonian rocks that are stacked in a series of southeast-dipping thrust slices with recumbent folds showing vergences to the northwest (Rast and Grant 1973; Arthaud and Matte 1977; Ruitenberg et al. 1973; Ruitenberg and McCutcheon 1982; Mosher and Rast 1984). The thrust slices cut the middle Westphalian Lancaster Formation.

The Variscan thrust faults along the Bay of Fundy Coast are attributable to the Carboniferous dextral displacement on the Cobequid-Chedabucto Fault (Arthaud and Matte 1977; Ruitenberg and McCutcheon 1982; Mosher and Rast 1984). More specifically, the faulting probably resulted from the collision of the Meguma Terrane with the Avalon Composite Terrane (Keppie et al. 1985). The thrusting on the Lutz Mountain Fault, Clover Hill Fault, and Harvey-Hopewell Fault (see above under "Significant Faults in the Maritimes Basin") is also thought to be related to this collision.

Variscan thrust faulting associated with dextral transcurrence has recently been documented on the continental shelf northeast of Newfoundland (Lefort and Haworth 1984; see also Figure 48). Seismic reflection, refraction, gravity and magnetic data have been utilized in correlating the structures seen in this thrust succession with those across the Variscan Front in Europe. It now seems that Variscan deformation occurs much farther north in the Appalachians than previously thought (Rast 1984).

INFLUENCE ON SEDIMENTATION

An inspection of the Horton and Windsor isopach maps (Figures 15 and 17), and a comparison of the thickness data thereon with the maps showing the regional faults in Atlantic Canada (Figures 9, 24, 35, 42, 43, and 44) will demonstrate that those faults are bounding subbasins with very thick Lower Carboniferous sequences (Figure 22). The Lower Carboniferous rocks in the Maritimes Basin mainly lie in a series of deep isolated subbasins and the Upper Carboniferous rocks (outside the Cumberland Subbasin) form a thinner cover overlying the adjoining platforms (Figures 12, 24, and 25).

The regional faults formed escarpments during Horton time in the Moncton Subbasin. The Memramcook, Albert, and Moncton formations are dominated by proximal alluvial-fan conglomerates near the Clover Hill Fault, and the Pollet-Caledonian Fault (Figure 24; Belt 1968; Pickerill *et al*. 1985; my unpublished data). The Belleisle Fault scarp on the north side of the Moncton Subbasin (Figure 24) has also given rise to abundant sharpstone debris flows (my unpublished data).

The Harvey-Hopewell Fault is bound to the south by coarse alluvial-fan deposits of the Hopewell Group (Webb 1963). These coarse fanglomerates were derived from the Caledonian upland (Webb 1963) and strongly suggest that the Harvey-Hopewell Fault had an early normal or oblique down-to-the-south component of movement preceding the known later thrusting (Ruitenberg and McCutcheon 1982). This early or proto-Harvey-Hopewell Fault defines the north margin of the Cumberland Subbasin (cf., Figures 42 and 19).

Belt (1968, 1969) documented numerous examples of Windsorian, Cansoan, and Cumberlandian fanglomerates in the Minas and Cumberland Subbasins adjacent to the Cobequid upland. He believed the facies gradations to be related to the Cobequid-Chedabucto Fault. Recent studies in the Stellarton Subbasin (Figure 22) have demonstrated that Westphalian B alluvial-fan deposits of the New Glasgow Conglomerate grade away from the Cobequid and Hollow faults and the Antigonish

Massif into fine-grained alluvial-plain and lacustrine shales (Yeo and Ruixiang 1986). The combined dextral displacement on the Cobequid and Hollow faults in this area is about 20 km.

The Long Range and Grand Lake faults in Newfoundland are bound on the northwest side by very thick proximal alluvial-fan deposits that grade northwestward into finer grained strata in the axial parts of the St. George's and Deer Lake subbasins (Figures 9 and 22). The fault-related strata there range in age from the Tournaisian Anguille Group to the Namurian Barachois Group (Belt 1968, 1969; Webb 1969; Hyde 1984).

Belt (1968) believed that coarse fanglomerates adjacent to the major faults in the Maritimes Basin demonstrated a dip-slip or normal component of movement on those faults. While this is true, it does not rule out the possibility of concurrent large transcurrent displacements on the faults. Comparisons with sedimentary basins in known strike-slip settings suggest that the Maritimes Basin, or more correctly, the separate subbasins were largely formed in a transpressive environment.

PALEOMAGNETIC EVIDENCE OF FAULTING

Morel and Irving (1978) published a series of paleomagnetic world maps for the Proterozoic and Paleozoic. Their Late Silurian to Permian interpretations are shown in Figures 49, 50, 51, 52, and 53. In the Late Silurian, the Appalachian-Caledonide fold belt formed by the closure of "Atlantic Three" and the collision of Laurentia with Baltica and Gondwana (Figure 49). During the Early to Middle Devonian (that is during the Acadian Orogeny), the paleomagnetic data indicates that Gondwana rotated sinistrally relative to Laurasia (Figure 50). Morris (1976) observed that Ordovician to Lower Devonian paleomagnetic poles from Britain were significantly different from contemporaneous poles in North America, yet the Upper Devonian poles from the two regions were similar. He concluded from this that approximately 1800 km of sinistral movement occurred during the Acadian Orogeny (Figure 54).

In the Morel and Irving (1978) paleomagnetic hypothesis, northwestern South America and eastern North America were in juxtaposition in the Early to Middle Devonian (Figure 50). By Late Devonian (Figure 51), South America had drifted south relative to North America (presumably along dextral transform or transcurrent faults) to assume a position due south of North America. This Middle to Late Devonian period of dextral faulting coincides with the inception of the Maritimes Basin and agrees with the known Late Devonian to Early Carboniferous strike-slip faults in Atlantic Canada (see above).

In Middle Carboniferous time (Figure 52), Morel and Irving (1978) believed "Atlantic Two" closed to form the Appalachian-Hercynian fold belt, and thus Pangea B. This supposedly took place by a northward drift of Gondwana and the second collision of South America with eastern North America during the Paleozoic and by sinistral displacement of Laurasia and Gondwana. Pangea B persisted essentially unchanged until the Early Permian (Figure 53). The Pangea B model of Morel and Irving has not been widely received, nor is it supported by geological evidence (cf. Arthaud and Matte 1977; Schenk 1971; Badham 1982). Keppie et al. (1985) wrote that, "... the Pangea B model would necessitate a major reorganization, with extravagant relative movements in the order of 3,500 km for which geological evidence is difficult to find, to achieve the Jurassic pre-drift configuration."

Kent and Opdyke (1978, 1979) published paleomagnetic data on the Late Devonian Catskill Red Beds of New York and the Early Carboniferous Barnett Formation of Texas. They compared the paleomagnetic poles in those rocks with synchronous rocks from eastern North America (Acadia) and determined that about 1 500 km of sinistral offset occurred in Carboniferous time (Figure 55). In this model, coastal New England and Maritime Canada did not become a part of eastern North America until the Late Carboniferous. Bedrock geological evidence does not support this interpretation. Viséan Windsor Group strata in the Maritimes Basin can be correlated across the supposed fault (Figure 55) and there are no demonstrated large-scale faults cutting Late Carboniferous strata.

The Kent and Opdyke (1978, 1979) hypothesis has recently been seriously questioned and essentially disproved by Irving and Strong (1984, 1985) and Seguin and Fyffe (1986). It has been shown that the Devonian and Carboniferous cratonic rocks have been overprinted by a Late Carboniferous and Permian chemical magnetization called the Kiaman Reversed Superchron (Figure 56b). Kent and Opdyke did not "clean" this magnetic event from their Devonian and Carboniferous cratonic samples, and therefore they compared Permian paleopoles on the craton with Late Devonian and Carboniferous poles in "Acadia" (Figures 56a, 56b). Irving and Strong have shown that motions of the magnitude called for by Kent and Opdyke did not take place in Newfoundland in the Viséan or later. The paleomagnetic results from Tournaisian to Namurian volcanic rocks across New Brunswick (Seguin and Fyffe 1986) rule out the possiblity of large-scale sinistral displacements during the Carboniferous. Irving and Strong (1985) conclude that the new data "... does not mean that motions of tens or even hundreds of kilometres ... did not occur.". This is critical. It allows sufficient lateral displacements to accommodate the formation of the Maritimes Basin.

PLATE TECTONIC INFERENCES

Regional steeply dipping faults from New England through Atlantic Canada demonstrate linear, sinuous, and anastomosing patterns and oblique or en echelon folds (Figures 33, 35, 42, 43, and 44) that are characteristic of strike-slip faults in transpressive settings (Harland 1971; see also Figures 68 and 73). The faults and related folds have deformed rocks of Late Devonian to Late Carboniferous age suggesting that transpression was prolonged.

Abundant angular clast debris flow conglomerates of mainly Horton age grade into sandstones and shales away from many of the faults suggesting the faults had a down-to-the-basin component of movement. Such fault-scarp breccias and conglomerates support, but do not prove, a rifting environment (Belt 1968; Howie and Barss 1975; Ruitenberg and McCutcheon 1982). Similar conglomerates are also characteristic of strike-slip or wrench tectonic settings (see below under "Comparisons of the Maritimes Basin With Sedimentary Basins in Known Strike-Slip Fault Zones").

Thrust faults, such as the Clover Hill and Harvey-Hopewell, and the "Variscan Front" structures along the Bay of Fundy coast, demonstrate that compression was locally intense in late Mississippian and early Pennsylvanian time.

Unrefuted paleomagnetic data indicates that substantial sinistral strike-slip fault movement may have occurred during the Acadian orogeny in the Maritimes and New England region (Morris 1976). The fault planes formed at this time were probably precursors for later Devonian and Early Carboniferous dextral fault movements responsible for the Maritimes Basin. Continental-scale strike-slip or megashear during Carboniferous or Permian time (Kent and Opdyke 1978, 1979; Arthaud and Matte 1977) did not take place in Atlantic Canada (Irving and Strong 1984, 1985; Seguin and Fyffe 1986).

Fault and fold tectogenesis and paleomagnetic data suggest that the Maritimes Basin evolved in a transpressive setting which may be a continued reflection of oblique convergence established during the Acadian orogeny (Keppie *et al*. 1985).

COMPARISON OF THE MARITIMES BASIN WITH SEDIMENTARY BASINS IN KNOWN STRIKE-SLIP FAULT ZONES

GEOTECTONIC SETTINGS

Sedimentary basins in strike-slip fault zones are known from many parts of the world. The best examples are those located along continental/oceanic or continental/continental transform (or transcurrent) plate boundaries (Figures 57, 58, and 59). These settings are analogous to the interpreted setting of the Maritimes Basin following the collision of the Acadian terranes.

BASIN MORPHOLOGIES

Basins in strike-slip regimes develop as pull-aparts by the mechanisms detailed in Figure 60 (Mann *et al*. 1983). Additionally, the pull-apart basins may be *simple* and bound by parallel, left- or right-stepping master faults (Figure 61A) or modified by an oblique median fault along nonparallel master faults (Figure 61B). Figure 61C shows that pull-aparts can nucleate on en echelon fractures and Figure 62 shows the continued development of such basins with prolonged displacement (cf. Figure 62E with the St. George's, Deer Lake, and White Bay subbasins of Newfoundland, Figures 22, 9, and 15).

Figures 63 and 64 (after Freund 1982) provide strike-slip models to explain the formation of rhomb grabens, wedge grabens, complex rift valleys, and uplifts associated with oblique motion on step faults. Figure 65 summarizes basin morphologies and attendant fault patterns in strike-slip settings (Reading 1980). The rhomb graben model of Freund (Figure 63a) shows a remarkable similarity to the Magdalen and Mabou subbasins during Horton deposition (Figures 22 and 15). The wedge graben model (Figure 63b) shows similarities with the Moncton Subbasin during Horton time (Figure 15).

Figure 66 shows examples of active rhomboidal pull-apart basins (cf. Figure 66A and 58 for location; cf. Figure 66C and 57B for location). The shape of the Miragoane Lakes Basin (Figure 66A) is comparable to the Moncton Subbasin during Horton time (cf. Figure 22 and the isopach map in Figure 15). The sedimentary history is analogous too (see below). The morphology and "left-step" faults in the Dead Sea Fault Zone (Figure 66C) are similar to those in the St. George's, Deer Lake, and White Bay subbasins of Newfoundland (Figures 22 and 9 and the Horton isopach map in Figure 15).

Figure 67 demonstrates an important morphological feature associated with many strike-slip zones - the formation of a "bulge", "push-up block" (Figure 57B), compressional overlap (Figure 61B) or uplift block (Figure 64). This feature is associated with nonparallel master faults or movement across a fault bend (Figure 60C). In the Moncton Subbasin (Figure 33), the Jordan Mountain basement inlier is believed to be a thrust push-up block related to strike-slip movement on the Indian Mountain-Smith Creek Fault (my unpublished data). A similar interpretation is suggested for the basement thrust slices against the Lutz Mountain Fault (Figure 34) and the Clover Hill Fault (Figure 35).

Figure 68 shows the morphology of basins and uplands in the wrench tectonic setting off southern California (cf. Figure 22 for the Maritimes Basin). The location of the cross sections in Figure 69 are shown on the map in Figure 68. Comparison of Figure 69 with the sections in Figure 23 for the Maritimes Basin serves to demonstrate the remarkable similarities in basin morphology. Note that the presence of horst-like and graben-like structures does not necessarily mean that the basin or subbasins have evolved by rifting - transpression is equally as likely.

SEDIMENTARY RECORD

Figure 70 depicts the sedimentary section resulting from a typical down-to-the-basin strike-slip fault in southern California. Coarse debris flow conglomerates against the fault typically grade basinward into fine-grained sandstone and shale. Similar stratigraphic records are recorded along the San Gabriel Fault in California (Figure 71) and the Highland Boundary Fault of Scotland (Figure 72). Belt (1968, 1969), Webb (1963, 1969), Howie and Barss (1974, 1975), and Pickerill et al. (1985) have described stratigraphic sections adjacent to major faults in the Maritimes Basin that are identical to those shown in Figures 70, 71, and 72. See for example, figure 16 in Pickerill et al. (1985).

Ballance (1980) has carrried out a detailed study on sedimentary facies in oblique-slip zones (Figures 74 and 75). He has shown that the facies are complex, but can be explained in terms of displacement on the basin bounding fault(s) and drainage patterns within the basin. Studies of this detail are needed on alluvial-fan complexes adjacent to the regional faults in the Maritimes Basin to determine the sense and magnitude of post-Acadian offsets.

The development of lakes in pull-apart basins is particularly relevant to the Maritimes Basin. Mann et al. (1983) have shown the relationship between lakes and alluvial fans in the Miragoane Lakes Basin and in the Dead Sea Fault

Zone (see Figure 66). Reading (1980) documented facies intertonguing of alluvial-fan and lacustrine beds in the Ridge Basin of California (Figure 71B). Identical facies associations occur within the Albert Formation in the Moncton Subbasin (Greiner 1962; Pickerill _et al_. 1985) and in the Merigomish Formation in the Stellarton Subbasin (Yeo and Ruixiang 1986).

IGNEOUS ACTIVITY

There is very little written on magmatism in strike-slip mobile zones. Mann _et al_. (1983) described recent volcanics adjacent to the San Andreas Fault Zone (Figure 76). They concluded that alkali basalts and tholeiites are found along continental strike-slip boundaries and calc-alkaline magmas are typical of transcurrent zones behind arcs and in areas of continental collision. The presence of tholeiites, calc-alkaline, and alkaline Devono-Carboniferous volcanics in the Maritimes Basin (Fyffe and Barr 1986; Dostal _et al_. 1983) appear to corroborate the findings of Mann _et al_. (1983).

It would seem from the meagre literature that there is a limited volume of volcanics associated with strike-slip faults and pull-apart basins. This is certainly true of the Maritimes Basin.

STRUCTURAL FEATURES (TRANSPRESSION AND TRANSTENSION)

Faults and "Push-ups": As described above under "Basin Morphologies", the faults in strike-slip regimes are curved, divergent-convergent, anastomosing, terminating, and side-stepping (Figure 65). Similar fault patterns are seen in the Maritimes Basin (cf. Figures 9, 33, 34, 35, 36, 37, 42, 43, and 44).

Nonparallel, side-stepped, master faults (Figure 61B) and curved strike-slip faults are characterized by thrusted push-up structures in a zone of compressional uplift (Figure 73). The Jordan Mountain Inlier in the Moncton Subbasin is believed to be a push-up structure (Figure 35). A similar origin is ascribed to the basement thrust slice along the Lutz Mountain Fault (Figure 34). Belt (1969) has described a sliver of granite basement along the Birchy Ridge Fault in Newfoundland (Figure 9) which may have risen in a push-up block.

Folds: Harland (1971) in his classic work in Spitsbergen described folds lying at oblique angles to, and generated synchronously with, strike-slip faults (cf. Figure 73, after Reading 1982). Simultaneously formed strike-slip faults and obliquely oriented folds have since been widely observed in transpressive settings and are demonstrated in the wrench tectonic basins southwest of the San Andreas Fault in California (Figure 68). Comparable fold and fault geometries have been mapped in the Maritimes Basin (Figures 33, 34, 35, 36, 37, 42, 43, and 44) and are taken as supporting evidence that the great majority of the regional post-Acadian faults in Atlantic Canada are dextral strike-slip structures.

Unconformities: Crowell (1974, p. 202) wrote of basins in strike-slip settings, "Inasmuch as much stretching and sagging and squeezing and uplift goes on hand in hand with sedimentation, complicated unconformities and overlaps are to be expected within the basins, and especially around their margins" (see Figure 78). Mann *et al*. (1983) described rapid facies changes and local unconformities resulting from syndepositional bulges near the edges of pull-apart basins. Local unconformities are common place in basins associated with transform/strike-slip fault zones (Reading 1982).

Local unconformities are characteristic of the Devono-Carboniferous sequences along the margins of the subbasins comprising the Maritimes Basin. For further details see the account above under "The Maritimes Basin", subsection "Folds and Unconformities". More extensive documentation is given in Bell (1929), Gussow (1953), Kelley (1967), Belt (1968), Howie and Barss (1974), and Ruitenberg and McCutcheon (1982).

COMPARISON OF THE MARITIMES BASIN WITH SEDIMENTARY BASINS IN KNOWN RIFT ENVIRONMENTS

GEOTECTONIC SETTINGS

For the purpose of comparison with the Maritimes Basin, it is only necessary to examine rifts underlain by continental crust. In this regard, we need only look at "failed rifts" - that is rifts that have not succeeded in developing into oceans (Burke 1978). The early formation of rifts is summarized in the first two panels of Figure 78.

One of the best known geological features on earth is the 5000 km long East African Rift system (Figure 79). It has traditionally been thought of as an incipient plate spreading margin, but may be in fact long-lived, and unrelated to plate divergence (Reading 1982).

Rifting in the Red Sea (Figure 80) has resulted in a narrow ocean (the Red Sea) and a rift-graben depression to the east (the Danakil Depression). The Danakil Depression is underlain by continental crust.

Failed rifts are common at triple junctions, where two arms succeed in forming an ocean, and the third arm becomes dormant. The most famous example of this type of rift (or aulacogen) is the Benue Trough (Figure 81).

The Baikal rift of Russia (Figure 82) is underlain by continental crust and has, like the East African Rift, been interpreted as an embryonic plate spreading axis. However, Tapponnier and Molner (1976) have ascribed the Baikal rift to extension associated with the collision of India and Asia.

BASIN MORPHOLOGIES

The form of rift basins in cross section can be seen in Figures 78 and 87. Rifting typically begins as a regional dome which is followed by lithosphere thinning and graben development along normal faults that dip towards the basin axis (Eaton 1979). Quite commonly basement uplands or horsts remain in the central region of the rift, for example, the Danakil Alps (Figure 80).

The East African Rift is an elongate arcuate trough over 5000 km in length. The geometry of this continental rift stands in marked contrast to the multiple subbasin morphology of the Maritimes Basin (cf. Figures 79 and 22).

Aulacogens, like the Benue trough (Figure 81) lie at a high angle to the continental margin (Reading 1982) and typically cut across an older fold belt upon which they foundered. This is in sharp contrast to the Maritimes Basin, which lies parallel to the axis of the Appalachian fold belt (cf. Figure 81 with Figures 12, 22, and 24).

Morphologically, the Baikal rift bears some striking similarities to the Maritimes Basin. It comprises a series of isolated subbasins separated by uplands and left and right off-stepping faults (cf. Figures 82 and 22). A note of caution is due here. In the past - prior to the recognition of pull-apart basins and their association with strike-slip mobile zones (Crowell 1974) - the word rift was used more or less as defined by White (1972), as "... any regional depression outlined by roughly parallel faults." In the newer terminology, the Baikal rift is not a true rift, in that it shows more than orthogonal extension. Displacements along both normal and wrench faults are dominant.

The late stage of continental rifting is characterized by a thermal subsidence phase (Bradley 1982). This is demonstrated by the so-called Carboniferous "sag" basins of Britain (Figures 83, 84, and 85). The sag basins are perhaps analogous to the Danakil Depression (Figure 80) and the Late Carboniferous "thin cover" in the Maritimes Basin (Belt 1968; see also Figures 24 and 25).

SEDIMENTARY RECORD

The early stage of rift development is characterized by sediment-starved basins, because drainage is away from the domal structure. Deep alkaline lakes are common in the floor of the rift (Figure 79). Somewhat later in the rift development, and particularly in semi-arid and temperate climates, proximal to distal alluvial fan complexes form adjacent to basin margin extensional faults (Miall 1981). In this regard, rift sedimentation is analogous to that seen in the Horton Group, and to a lesser extent, the Canso and Cumberland groups in the Maritimes Basin. Rifts in semi-arid climates along continental margins can be inundated by marine waters leaving a record of carbonates and evaporites. The marine strata of the Danakil Depression (Figure 80) have been compared to the Windsor rocks in the Maritimes Basin (McCutcheon 1981).

The late stages of continental rift development is dominated by fluvial processes and more widely distributed mature sediments associated with the "sag" basins (Leeder 1982). The Late Carboniferous fluviatile sandstones and coal measures of Britain and Maritime Canada provide an inviting parallel.

Sedimentation in continental "failed rifts" stands in stark contrast to the sedimentary record in rift basins on passive oceanic margin such as the Baltimore Canyon trough (Figure 86).

IGNEOUS ACTIVITY

Rifts are associated with volcanism, and usually voluminous volcanism (Riecker 1979). Logatchev (1978) has, however, divided rifts into two stages and described strong volcanism and weak volcanism rifts (Figure 87). The limited volume of volcanic rocks in the Maritimes Basin (Dostal et al. 1983; Fyffe and Barr 1986), it would seem, necessitates that it accordingly be classified as a low volcanicity rift. The low volcanicity Rhine graben is characterized by mainly alkaline volcanics; in contrast, the Baikal rift contains a complex alteration of basaltic lavas with alkaline, transitional, and tholeiitic affinities (Barberi et al. 1982). The late volcanics in the Baikal rift are alkaline. The low volume and widely distributed volcanic rocks of the Baikal rift (cf. Figure 82 with Figures 26 and 27), and the similarity in evolutionary chemical trends of the volcanics with those in the Maritimes Basin (cf. Barberi et al. 1982 with Fyffe and Barr 1986 and Dostal et al. 1983) present a strong analogy. This is perhaps a reflection of the comparable wrench tectonic settings of the two basins.

The volcanic history of the Maritimes Basin is not at all comparable to conventional rift basins that are dominated by tholeiitic dyke swarms and sills (Figures 88 and 89), and voluminous flows (Figure 90). Some continental rifts are dominated by felsic flows and tuffs (see Riecker 1979, and the papers listed therein).

STRUCTURAL FEATURES

Faults: Rift zones are characterized by down-to-the-basin normal growth faults that accommodate lithospheric thinning (Kursten 1974; Eaton 1979; Kelley 1979; Manley 1979; see Figure 91 after Bruce 1983). Growth or listric faults are active during sedimentation and are formed primarily through gravitational gliding (Figures 91A, and 91B). They are commonly accompanied by antithetic (adjustment) faults (Figures 91C and 91D) as documented for example by Kelley (1979) in the Albuquerque and Espanola basins of New Mexico and by Kursten (1974) on the west side of the Danakil Depression. The early sedimentary deposits are typically cut by later normal faults resulting from continued extension (Kursten 1974; Bruce 1983). Many basin-forming and intrabasinal faults are reactivated basement structures (Kelley 1979; Donaldson and Shumaker 1981).

Kelley (1979) has shown that rift basins are not always morphologically simple horst and graben depressions dominated by only normal faults. He notes that six basins in the Rio Grande Rift of Mexico are translated easterly by "right echeloning" of the basin border faults that are arranged in relay. The basins appear to have deformed as units separated by diagonal faults involving twisting and pivotal movements.

There are no reported examples of listric normal faults or associated antithetic faults in the Maritimes Basin. However, Belt (1968, 1969) has shown that most of the major faults either bordering or within the Maritimes Basin are accompanied by alluvial-fan complexes implying a component of downthrow on the basinward side (see above under "Significant Faults in the Maritimes Basin").

Folds: Syn-sedimentary slump folds associated with rapid deposition and tectonic instability are common in rift sediments (Kursten 1974). Rollover folds (anticlines) are typically associated with growth faults (Figures 91A, 91B, 91C, 91D). Kelley (1979) recorded local monoclines and broad homoclines related to the tilting of major blocks in the Albuquerque Basin of New Mexico. Kursten (1974) described local folds associated with tilted blocks in the Danakil Depression.

Compressional folds cannot form during rifting. Accordingly, the Devono-Carboniferous rocks of the Maritimes Basin were not folded in a "rift environment", but were deformed as a result of compression or transpression.

Unconformities: Unconformities, and particularly local unconformities, are common in rift basins and result from block faulting and tilting along the basin margin and within intrabasinal blocks. Manley (1979) recorded one basin-wide unconformity and two basin-margin unconformities in the Espanola Basin in the Rio Grande Rift of New Mexico (see Figure 92). The local unconformities in the Maritimes Basin may have arisen by tectonics associated with rifting; rift tectonic and wrench tectonic settings cannot be differentiated solely on the presence or absence of unconformities.

CONCLUSIONS

The late Middle Devonian to Early Permian Maritimes Basin overlies six major late Precambrian to mid-Paleozoic terranes and composite terranes of the Northern Appalachians (Williams and Hatcher 1982; Keppie et al. 1985). The terranes, as designated by Keppie et al. (1985), are bound by mélanges or faults, the latter with complex histories involving transcurrent motions. The Appalachian-Caledonian orogen is now being seen as much more than the simple opening and closing of the Iapetus Ocean as envisaged by Wilson (1966), Dewey (1969), and Dewey and Bird (1970). Williams and Hatcher (1982) and Keppie et al. (1985) describe the orogen as resulting from the collision and oblique collision in the mid-Paleozoic of numerous suspect terranes many of which can be shown to have transcurrent fault boundaries. The convergence and oblique convergence established during the mid-Paleozoic appears to have waned somewhat, but more or less lasted throughout the Late Devonian to Early Permian. This gave rise to newly generated strike-slip faults and continued movement on the established terrane boundary sutures.

The Maritimes Basin formed during this period of transcurrence and convergence. The basin comprises a series of wedge-shaped, rhombic, and elongate troughs that are analogous to basins formed in wrench tectonic environments (cf. Crowell 1974; Ballance and Reading 1980; Freund 1982; and Mann _et al_. 1983). The basin-margin alluvial-fan complexes, and axial fluvial/lacustrine sequences in the individual subbasins have been described by Bell (1929), Gussow (1953), Belt (1968), Fralick and Schenk (1981) and many others. The thick sedimentary sections in individual subbasins are comparable to the sedimentary sequences described in wrench tectonic or pull-apart basins in California, New Zealand, and the Caribbean (Crowell 1974; Miall 1981; Mann _et al_. 1983; Ballance and Reading 1980, and the papers therein). The widespread, thin Late Carboniferous deposits of the Maritimes Basin are analogous to the "sag" basin deposits of Leeder (1982) and represent the thermal subsidence phase of rift or pull-apart basins (Bradley 1982).

The volcanic rocks in the Maritimes Basin are limited in volume and are chemically similar to those in strike-slip ensialic basins (Mann _et al_. 1983) and to those in low volcanicity continental rifts (Logatchev 1978). The Late Devonian and Early Carboniferous granitoid plutonic rocks within and adjacent to the Maritimes Basin were intruded into a thickened-crust (Fyffe _et al_. 1981) and are consequently not ascribed to rifting. This is supported by the absence of Late Devonian and Carboniferous tholeiitic dykes (cf. Francis 1978).

A compilation of data on the regional faults affecting the Maritimes Basin indicates that most of the faults show dextral transcurrent and basinward dip-slip movements (Webb 1963, 1969; Belt 1968, 1969). Many of the faults are probably reactivated basement structures. The association of en echelon folds, push-up blocks, and local unconformities adjacent to the major faults suggest a transpressional origin (Harland 1971; Crowell 1974; Rodgers 1980; Howell _et al_. 1980; Mann _et al_. 1983).

Carboniferous (Hercynian or Variscan) convergence is shown by the dextral movement on the Cobequid-Chedabucto Fault (Webb 1969; Belt 1968; Keppie _et al_. 1985) and the collision of the Meguma terrane with the Avalon composite terrane in southern coastal New Brunswick (Rast and Grant 1973; Ruitenberg _et al_. 1973; Ruitenberg and McCutcheon 1982; Mosher and Rast 1984). The thrusting there cuts the middle Westphalian Lancaster Formation. The evidence on all the faults within the Maritimes Basin, when taken together, demonstrates that transpressional and transtensional deformations occurred simultaneously in closely adjacent areas (cf. Fralick and Schenk 1981).

Recent paleomagnetic data (Irving and Strong 1984, 1985; Seguin and Fyffe 1986) has shown that 1500 km of sinistral transcurrent displacement between the North American craton and Acadia did not take place in Carboniferous time as argued by Kent and Opdyke (1978, 1979). The new paleomagnetic data does not, however, rule out the possibility of tens or even hundreds of kilometres of transcurrent movement during the formation of the Maritimes Basin.

The Maritimes Basin and its associated subbasins have been described as rift basins (Belt 1968; White 1972; Howie and Barss 1974; Ruitenberg and McCutcheon 1982). The plate tectonic synthesis presented here, the regional fault geometries and their movements, the subbasin morphologies and their stratigraphic facies records, and the post-Acadian volcanic and plutonic history within and adjacent to the Maritimes Basin do not support an origin in a rift environment. The evidence demonstrates, as Fralick and Schenk (1981), Bradley (1982), Hyde (1984), and Yeo and Ruixiang (1986) have argued, that the late Paleozoic basins are pull-aparts that have evolved in a regional dextral strike-slip fault zone.

RECOMMENDATIONS FOR FURTHER STUDY

Paleocurrent studies are badly needed in many formations to determine their provenance. Detailed compositional studies on clasts are required to provide closer correlation with distinctive rock types in the source area(s). This information can be used to help determine the amount of lateral offset on basin-margin faults.

Further spore and other age dates on individual formations and facies are needed. This will assist in establishing stratigraphic relations and place closer time restrictions on deformation and unconformities.

Detailed fold, fault, and fracture pattern studies in the Carboniferous rocks are required so that the sense of late Paleozoic fault movements can be determined more exactly. This will help distinguish post-Acadian from earlier Paleozoic displacements.

REFERENCES

ARTHAUD, F. and MATTE, P. 1977. Late Paleozoic strike-slip faulting in southern Europe and north Africa: result of a right-lateral shear zone between the Appalachians and the Urals. Geological Society of America Bulletin, Volume 88, pp. 1305-1320.

BADHAM, J.P.N. 1982. Strike-slip orogens - an explanation for the Hercynides. Geological Society of London Journal, Volume 139, pp. 493-504.

BALL, F.D., SULLIVAN, R.M. and PEACH, A.R. 1981. Carboniferous Drilling Project. Department of Forests, Mines and Energy, Mineral Resources Branch, Report of Investigation No. 18, 107 p.

BALLANCE, P.E. 1980. Models of sediment distribution in non-marine and shallow marine environments in oblique-slip fault zones. In Sedimentation in Oblique-slip Mobile Zones, P.F. Ballance and H.G. Reading (editors). International Association of Sedimentologists, Special Publication 4, Blackwell Scientific, Boston, Massachusetts, pp. 229-236.

BALLANCE, P.F. and READING, H.G. 1980. Sedimentation in oblique-slip mobile zones: an introduction. In Sedimentation in Oblique-slip Mobile Zones, P.F. Ballance and H.G. Reading (editors). International Association of Sedimentologists, Special Publication No. 4, pp. 1-5.

BARBERI, F., SANTACROCE, R., and VARET, J. 1982. Chemical aspects of rift magmatism. In Continental and Oceanic Rifts, G. Palmason (editor). American Geophysical Union and Geological Society of America, Geodynamic Series, Volume 8, pp. 223-256.

BARR, S.M., BRISEBOIS, D. and MACDONALD, A.S. 1985. Carboniferous volcanic rocks of the Magdalen Islands, Gulf of St. Lawrence. Canadian Journal of Earth Sciences, Volume 22, pp. 1679-1688.

BELL, W.A. 1929. Horton-Windsor District, Nova Scotia. Geological Survey of Canada, Memoir 155, 268 p.

BELT, E.S. 1968. Post-Acadian rifts and related facies, eastern Canada. In Studies of Applachian Geology, Northern and Maritime, E-An Zen, W.S. White, J.B. Hadley, and J.B. Thompson, Jr. (editors). Intersicence, Toronto, pp. 95-113.

BELT, E.S. 1969. Newfoundland Carboniferous stratigraphy and its relation to the Maritimes and Ireland. In North Atlantic Geology and Continental Drift (a symposium), M. Kay (editor). American Association of Petroleum Geologists, Memoir 12, pp. 734-753.

BIRD, J.M. and DEWEY, J.F. 1970. Lithosphere plate - continental margin tectonics and the evolution of the Appalachian Orogen. Geological Society of America, Bulletin, Volume 81, pp. 1031-1060.

BLUCK, B.J. 1969. Old Red Sandstone and other Paleozoic conglomerates of Scotland. In North Atlantic Geology and Continental Drift (a symposium), M Key (editor). American Association of Petroleum Geologists, Memoir 12, pp. 711-723.

BLUCK, B.J. 1980. Evolution of strike-slip fault-controlled basin, Upper Old Red Sandstone, Scotland. In Sedimentation in Oblique-slip Mobile Zones, P.F. Ballance and H.G. Reading (editors). International Association of Sedimentologists, Special Publication No. 4, pp. 63-78.

BRADLEY, D.C. 1982. Subsidence in late Paleozoic basins in the northern Appalachians. Tectonics, Volume 1, pp. 107-123.

BRUCE, C.H. 1983. Shale tectonics, Texas coastal area growth faults. In Seismic Expression of Structural Styles - A Picture and Work Atlas, A.W. Bally (editor). American Association of Petroleum Geologists, Studies in Geology Series No. 15, Volume 2, pp. 2.3.2-2-2.3.1-10.

BURKE, K. 1978. Evolution of continental rift systems in the light of plate tectonics. In Tectonics and Geophysics of Continental Rifts, I.B. Ramberg and E.R. Neumann (editors). D. Reidel Publishing Company, Dordrecht, Holland, pp. 1-9.

CROWELL, J.C. 1974. Origin of Late Cenozoic basins in southern California. In Tectonics and Sedimentation, W.R. Dickinson (editor). Society of Economic Paleontologists and Mineralogists, Special Publication No. 22, pp. 190-204.

DEWEY, J.F. 1969. Evolution of the Appalachian/Caledonian Orogen. Nature, Volume 222, pp. 124-129.

DONALDSON, A.C. and SHUMAKER, R.C. 1981. Late Paleozoic molasse of central Appalachians. In Sedimentation and Tectonics in Alluvial Basins, A.D. Miall (editor). Geological Association of Canada, Special Paper 23, pp. 99-124.

DOSTAL, J., KEPPIE, J.D., and DUPUY, C. 1983. Petrology and geochemistry of Devono-Carboniferous volcanic rocks in Nova Scotia. Maritime Sediments and Atlantic Geology, Volume 19, pp. 59-71.

DOSTAL, J., KEPPIE, J.D., and MURPHY, J.B. 1986. Avalonian volcanic rocks of Nova Scotia. Atlantic Geoscience Society, Colloquium Abstracts on Current Research in the Atlantic Provinces, 36 p.

EATON, G.P. 1979. A plate-tectonic model for Late Cenozoic crustal spreading in the western United States. In Rio Grande Rift: Tectonics and Magmatism, R.E. Riecker (editor). American Geophysical Union, Washington, D.C., pp. 7-32.

FRALICK, P.W. and SCHENK, P.E. 1981. Molasse deposition and basin evolution in a wrench tectonic setting: the late Paleozoic, eastern Cumberland Basin, Maritime Canada. In Sedimentation and Tectonics in Alluvial Basins, A.D. Miall (editor). Geological Association of Canada, Special Paper 23, pp. 77-97.

FRANCIS, E.H. 1978. The Midland Valley as a rift, seen in connection with the Late Paleozoic European rift system. In Tectonics and Geophysics of Continental Rifts, I.B. Ramberg and E.R. Neumann (editors). D. Reidel Publishing Company, Dordrecht, Holland, pp. 133-147.

FREUND, R. 1982. The role of shear in rifting. In Continental and Oceanic Rifts, G. Palmason (editor). American Geophysical Union, Washington, D.C., Geodynamic Series, 8, 309 p.

FYFFE, L.R. and BARR, S.M. 1986. Petrochemistry and tectonic significance of Carboniferous volcanic rocks in New Brunswick. Canadian Journal of Earth Sciences, Volume 23, pp. 1243-1256.

FYFFE, L.R., PAJARI, G.E. (Jr.), and CHERRY, M.E. 1981. The Acadiain plutonic rocks of New Brunswick. Maritime Sediments and Atlantic Geology, Volume 17, pp. 23-36.

GATES, A.E., SIMPSON, C. and GLOVER, L. 1986. Appalachian Carboniferous dextral strike-slip faults: an example from Brookneal, Virginia. Tectonics, Volume 5, pp. 119-133.

GREINER, H.R. 1962. Facies and sedimentary environments of Albert shale, New Brunswick. American Association of Petroleum Geologists, Bulletin, Volume 46, pp. 219-234.

GUSSOW, W.C. 1953. Carboniferous stratigraphy and structural geology of New Brunswick, Canada. American Association of Petroleum Geologists, Bulletin, Volume 37, pp. 1713-1816.

HARLAND, W.B. 1971. Tectonic transpression in Caledonian Spitsbergen. Geological Magazine, Volume 108, No. 1, pp. 27-42.

HASZELDINE, R.S. 1984. Carboniferous North Atlantic paleogeography: stratigraphic evidence for rifting, not megashear or subduction. Geological Magazine, Volume 121, pp. 443-463.

HAWORTH, R.T. 1975. The Development of Atlantic Canada as a result of continental collision - evidence from offshore gravity and magnetic data. In Canada's Continental Margins and Offshore Petroleum Exploration, C.J. Yorath, E.R. Parker, and D.J. Glass (editors). Canadian Society of Petroleum Geologists, Memoir 4, pp. 59-77.

HOWELL, D.G., CROUCH, J.K., GREENE, H.G., MCCULLOCH, D.S., and VEDDER, J.G. 1980. Basin development along the late Mesozoic and Cainozoic California margin: a plate tectonic margin of subduction, oblique subduction and transform tectonics. In Sedimentation in Oblique-slip Mobile Zones, P.F. Ballance and H.G. Reading (editors). International Association of Sedimentologists, Special Publication No. 4, pp. 43-62.

HOWIE, R.D. and BARSS, M.S. 1974. Upper Palezoic rocks of the Atlantic provinces, Gulf of St. Lawrence, and adjacent continental shelf. In Offshore Geology of Eastern Canada. Geological Survey of Canada, Paper 74-30, Volume 2, pp. 35-50.

HOWIE, R.D. and BARSS, M.S. 1975. Paleogeography and sedimentation in the Upper Paleozoic, eastern Canada. In Canada's Continental Margins and Offshore Petroleum Exploration. Canadian Society of Petroleum Geologists, Memoir 4, pp. 45-57.

HYDE, R.D. 1984. Oil shales near Deer Lake, Newfoundland. Geological Survey of Canada, Open File Report OF 1114, 10 p.

IRVING, E. and STRONG, D.F. 1984. Evidence against large-scale Carboniferous strike-slip faulting in the Appalachian-Caledonian orogen. Nature, Volume 310, pp. 762-764.

IRVING, E. and STRONG, D.F. 1985. Paleomagnetism of rocks from Burin Penninsula, Newfoundland: Hypothesis of Late Paleozoic displacement of Acadia criticized. Journal of Geophysical Research, Volume 90, No. B2, pp. 1949-1962.

KELLEY, D.G. 1967. Some aspects of Carboniferous stratigraphy and depositional history in the Atlantic provinces. In Collected Papers in Geology of the Atlantic Region, E.R.W. Neale and H. Williams (editors). Geological Association of Canada, Special Paper No. 4, pp. 213-228.

KELLEY, D.G. 1970. Geology of southeastern Canada. In Geology and Economic Minerals of Canada, R.J.W. Douglas (editor). Geological Survey of Canada, Economic Geology Report 1, pp. 284-296.

KELLEY, V.C. 1979. Tectonics, Middle Rio Grande Rift, New Mexico. In Rio Grande Rift: Tectonics and Magmatism, R.E. Riecker (editor), American Geophysical Union, Washington, D.C., pp. 57-70.

KENNEDY, M.J. 1979. The continuation of the Canadian Appalachians into the Caledonides of Britain and Ireland. In The Caledonides of the British Isles - Reviewed, A.L. Harris, C.H. Holland, and B.E. Leake (editors). Geological Society of London, Special Publication No. 8, pp. 33-64.

KENT, D.V. and OPDYKE, N.D. 1978. Paleomagnetism of the Devonian Catskill red beds: evidence for motion of the coastal New England-Canadian maritime region relative to cratonic North America. Journal of Geophysical Research, Volume 83, No. B9, pp. 4441-4450.

KENT, D.V. and OPDYKE, N.D. 1979. The Early Carboniferous paleomagnetic field of North America and its bearing on tectonics of the northern Appalachians. Earth and Planetary Science Letters, Volume 4, pp. 365-372.

KEPPIE, J.D. 1985. The Appalachian Collage. In The Caledonide Orogen, Scandinavia and Related Areas, D.G. Gee and B. Sturt (editors). Wiley, New York, pp. 1-9.

KEPPIE, J.D., CURRIE, K.L., MURPHY, J.B., PICKERILL, R.K., FYFFE, L.R., and ST-JULIEN, P. 1985. Appalachian geotraverse (Canadian mainland). R.K. Pickerill, C.K. Mawer, and L.R. Fyffe (editors). Geological Association of Canada, Mineralogical Association of Canada, "Fredericton 85", Field Excursions, Volume 1, 181 p.

KING, L.H., HYNDMAN, R.D., and KEEN, C.E. 1975. Geological development of the continental margin of Atlantic Canada. Geoscience Canada, Volume 2, pp. 26-35.

KURSTEN, M.O.C. 1974. Tectonic inventory of the Danakil Depression. In Afar Depression of Ethiopia, A. Pilger and A. Rosler (editors). Inter-Union Commission on Geodynamics, Stuttgart, Germany, Scientific Report No. 14, pp. 170-174.

LEEDER, M.R. 1982. Upper Paleozoic basins of the British Isles - Caledonide inheritance versus Hercynian plate margin processes. Geological Society of London, Journal, Volume 129, pp. 479-491.

LEFORT, J.P. and HAWORTH, R.T. 1984. Geophysical evidence for the extension of the Variscan front on the Canadian continental margin: geodynamic and paleogeographic consequences. In Variscan Tectonics of the North Atlantic Region, D.H.W. Hutton and D.J. Sanderson (editors). Blackwell Scientific Publications, Boston, pp. 219-231.

LEFORT, J.P. and VAN DER VOO, R. 1981. A kinetic model for the collision and complete suturing between Gondwanaland and Laurussia in the Carboniferous. Journal of Geology, Volume 89, pp. 537-550.

LOGATCHEV, N.A. 1978. Main features of evolution and magmatism of continental rift zones in the Cenozoic. In Tectonics and Geophysics of Continental Rifts, I.B. Ramberg and E.R. Neumann (editors). D. Reidel Publishing Company, Dordrecht, Holland, pp. 351-366.

MACAULEY, G. and BALL, F.D. 1984. Oil shales of the Big Marsh and Pictou areas. Geological Survey of Canada, Institute of Sedimentary and Petroleum Geology, Open File Report OF 1037, 57 p.

McCUTCHEON,S.R. 1981. Stratigraphy and paleogeography of the Windsor Group in southern New Brunswick. New Brunswick Department of Forests, Mines and Energy, Mineral Resources Branch, Open File Report 81-31, 210 p.

MANLEY, K. 1979. Stratigraphy and structure of the Espanola Basin, Rio Grande Rift, New Mexico. In Rio Grande Rift: Tectonics and Magmatism, R.E. Riecker (editor). American Geophysical Union, Washington, D.C., pp. 71-86.

MANN, P., HAMPTON, M.R., BRADLEY, D.C., and BURKE, K. 1983. Development of pull-apart basins. Journal of Geology, Volume 91, pp. 529-554.

MIALL, A.D. 1981. Alluvial sedimentary basins: tectonic setting and basin architecture. In Sedimentation and Tectonics in Alluvial Basins, A.D. Miall (editor). Geological Association of Canada, Special Paper 23, pp. 1-33.

MOREL, P. and IRVING, E. 1978. Tentative paleocontinental maps for the Early Phanerozoic and Proterozoic. Journal of Geology, Volume 86, pp. 535-561.

MOREL, P. and IRVING, E. 1981. Paleomagnetism and the evolution of Pangea. Journal of Geophysical Research, Volume 86, No. B3, pp. 1858-1872.

MORRIS, W.A. 1976. Transcurrent motion determined paleomagnetically in the northern Appalachians and Caledonides and the Acadian Orogeny. Canadian Journal of Earth Sciences, Volume 13, pp. 1236-1243.

MOSHER, S. and RAST, N. 1984. The deformation and metamorphism of Carboniferous rocks in Maritime Canada and New England. In Variscan Tectonics of the North Atlantic Region, D.H.W. Hutton and D.J. Sanderson (editors). Blackwell Scientific Publications, Boston, pp. 233-243.

PHILLIPS, W.E.A., KENNEDY, M.J., and DUNLOP, G.M. 1969. Geologic comparison of western Ireland and northeastern Newfoundland. In North Atlantic Geology and Continental Drift (a symposium), M. Kay (editor). American Association of Petroleum Geologists, Memoir 12, pp. 194-211.

PICKERILL, R.K. and CARTER, D. 1980. Sedimentary facies and depositional history of the Albert Formation. New Brunswick Department of Forests, Mines and Energy, Mineral Resources Branch, Open File Report 80-2, 132 p.

PICKERILL, R.K., CARTER, D., and ST. PETER, C. 1985. Albert Formation - oil shales, lakes, fans and deltas. Geological Association of Canada, Mineralogical Association of Canada, Excursion 6, 75 p.

POLL, van de, H.W. 1970. Stratigraphy and sedimentological aspects of Pennsylvanian strata in southern New Brunswick. Unpublished Ph.D. thesis, University College of Swansea, University of Wales, United Kingdom, 199 p.

POOLE, W.H. 1967. Tectonic evolution of Appalachian region of Canada. In Collected Papers in Geology of the Atlantic Region, E.R.W. Neale and H. Williams (editors). Geological Association of Canada, Special Paper No. 4, pp. 9-51.

RAST, N. 1984. The Alleghenian orogeny in eastern North America. In Variscan Tectonics of the North Atlantic Region, D.H.W. Hutton and D.J. Sanderson (editors). Blackwell Scientific Publications, Boston, pp. 197-217.

RAST, N. and GRANT, R.H. 1973. The Variscan Front in southern New Brunswick. In Field Guide to Excursions 4-11, N. Rast (editor). New England Intercollegiate Geological Conference, pp. 4-11.

RAST, N., KENNEDY, M.J., BLACKWOOD, R.F. 1976. Comparison of some tectonostratigraphic zones in the Appalachians of Newfoundland and New Brunswick. Canadian Journal of Earth Sciences, Volume 13, pp. 868-875.

READING, H.G. 1980. Characteristics and recognition of strike-slip fault systems. In Sedimentation in Oblique-slip Mobile Zones, P.F. Ballance and H.G. Reading (editors). International Association of Sedimentologists, Special Publication No. 4, pp. 7-26.

READING, H.G. 1982. Sedimentary basins and global tectonics. Geologists' Association Proceedings, Volume 93, pp. 321-350.

RIECKER, R.F. (editor). 1979. Rio Grande Rift: tectonics and magmatism. American Geophysical Union, Washington, D.C., 438 p.

RODGERS, D.A. 1980. Analysis of pull-apart basin development produced by en echelon strike-slip faults. In Sedimentation in Oblique-slip Mobile Zones, P.F. Ballance and H.G. Reading (editors). International Association of Sedimentologists, Special Publication No. 4, pp. 27-41.

RUITENBERG, A.A. and McCUTCHEON, S.R. 1982. Acadian and Hercynian structural evolution of southern New Brunswick. In Major Structural Zones and Faults of the Northern Appalachians, P. St-Julien and J. Béland (editors). Geological Association of Canada, Special Paper 24, IGCP Project 27, pp. 131-148.

RUITENBERG, A.A., VENUGOPAL, D.V., and GILES, P.S. 1973. "Fundy Cataclastic Zone", New Brunswick: evidence for post-Acadian penetrative deformation. Geological Society of America Bulletin, Volume 84, pp. 3029-3044.

RUITENBERG, A.A., FYFFE, L.R., MCCUTCHEON, S.R., ST. PETER, C.J., IRRINKI, R., and VENUGOPAL, D.V. 1977. Evolution of pre-Carboniferous tectonostratigraphic zones in New Brunswick Appalachians. Geoscience Canada, Volume 4, pp. 171-181.

RUITENBERG, A.A., GILES, P.S., VENUGOPAL, D.V., BUTTIMER, S.M., McCUTCHEON, S.R. and CHANDRA, J. 1979. Geology and mineral deposits, Caledonia area. New Brunswick Department of Natural Resources, Mineral Resources Branch, Memoir 1, 213 p.

ST. PETER, C. 1979. Geology of Wapske-Odell River-Arthurette region, New Brunswick. New Brunswick. New Brunswick Department of Natural Resources, Mineral Resources Branch, Map Report 79-2, 32 p.

SCHENK, P. 1971. Southeastern Atlantic Canada, northwestern Africa, and continental drift. Canadian Journal of Earth Sciences, Volume 8, pp. 1218-1251.

SEGUIN, M.K. and FYFFE, L. 1986. Paleomagnetism of lower Carboniferous (Tournaisian to Namurian) volcanic rocks of New Brunswick, Canada, and its tectonic implications. Tectonophysics, Volume 122, pp. 357-379.

SHERIDAN, R.E. and DRAKE, C.L. 1968. Seaward extension of the Canadian Appalachians. Canadian Journal of Earth Sciences, Volume 5, pp. 337-373.

SNOKE, A.W. and SECOR, D.T. (Jr.). 1982. The eastern Piedmont fault system and its relationship to Alleghanian tectonics in the southern Appalachians: a discussion. Journal of Geology, Volume 90, pp. 209-211.

TAPPONNIER, P. and MOLNAR, P. 1976. Slip-line field theory and large-scale continental tectonics. Nature, Volume 264, pp. 319-324.

UTTING, J. 1980. Palynology of the Windsor Group (Mississippian) in a borehole at Stewiacke, Shubenacadie Basin, Nova Scotia. Canadian Journal of Earth Sciences, Volume 17, pp. 1031-1045.

WEBB, G.W. 1963. Occurrence and exploration significance of strike-slip faults in southern New Brunswick, Canada. American Association of Petroleum Geologists, Bulletin, Volume 47, pp. 1904-1927.

WEBB, G.W. 1969. Paleozoic wrench faults in Canadian Appalachians. In North Atlantic Geology and Continental Drift (a symposium), M. Kay (editor). American Association of Petroleum Geologists, Memoir 12, pp. 754-786.

WHITE, R.D. 1972. The Cumberland Basin - a possible rift. Canadiani Institute of Mining, Bulletin, Volume LXXXV, pp. 267-272.

WILLIAMS, E.P. 1974. Geology and petroleum possibilities in and around Gulf of St. Lawrence. American Association of Petroleum Geologists, Bulletin, Volume 58, pp. 1137-1155.

WILLIAMS, H. 1979. Appalachian Orogen in Canada. Canadian Journal of Earth Sciences, Volume 16, pp. 792-807.

WILLIAMS, H. and HATCHER, R.D. (Jr.). 1982. Suspect terranes and accretionary history of the Appalachian orogen. Geology, Volume 10, pp. 530-536.

WILSON, J.T. 1966. Did the Atlantic close and then re-open? Nature, Volume 211, pp. 676-681.

WINDLEY, B.F. 1982. The evolving continents (2nd Edition). John Wiley and Sons, Toronto, 399 p.

YEO, G.M. and RUIXIANG, G. 1986. Late Carboniferous tectonics and sedimentation in Stellarton Gap, Nova Scotia. In Abstracts of the Atlantic Geoscience Society Colloquium on Current Research in the Atlantic Provinces, 36 p.

ZIEGLER, P.A. 1984. Caledonian and Hercynian crustal consolidation of western and central Europe - a working hypothesis. Geology of Mijnbouw, Volume 63, pp. 93-108.

FIGURES

(FIGURES 4, 15, 17, 19 and 21 are in back pocket)

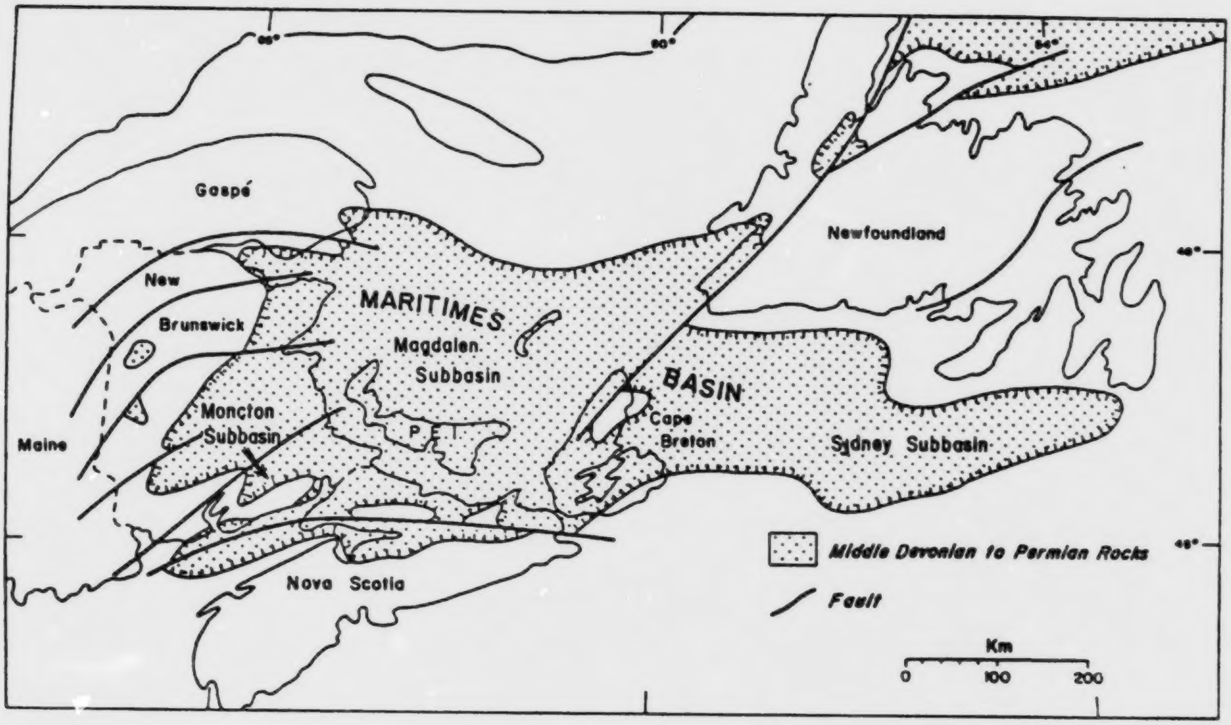

Gaspé
New
Brunswick
Maine
MARITIMES
Magdalen
Subbasin
Moncton
Subbasin
P.E.I.
BASIN
Cape
Breton
Sydney Subbasin
Newfoundland
Nova Scotia
Middle Devonian to Permian Rocks
Fault
Km
0
100
200

FIGURE 1. Distribution of Middle Devonian to Permian strata in the Maritimes Basin of eastern Canada (after Fyffe and Barr in press).

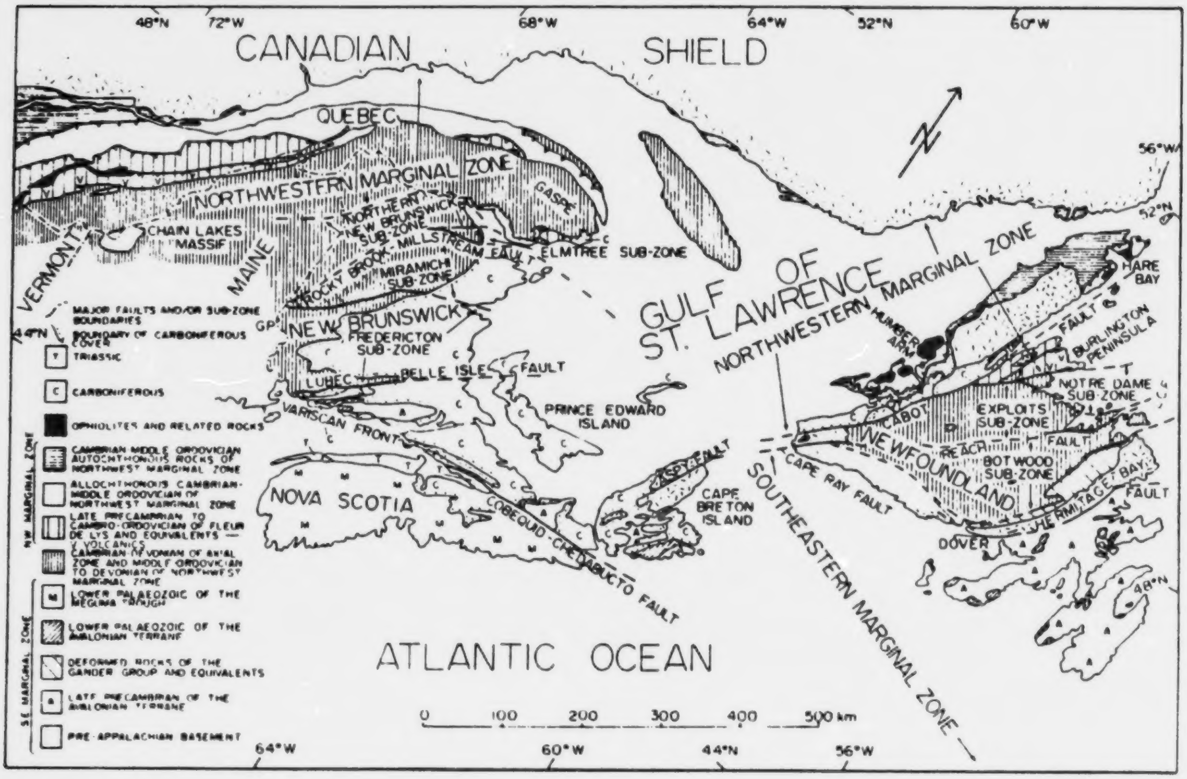

48°N
72°W
68°W
64°W
52°N
60°W
56°W
52°N
44°N
48°N
64°W
60°W
44°N
56°W
CANADIAN SHIELD
QUEBEC
NORTHWESTERN MARGINAL ZONE
NORTHERN NEW BRUNSWICK SUB-ZONE
GASPE
CHAIN LAKES MASSIF
VERMONT
MAINE
ROCKY BROOK - MILLSTREAM FAULT
MIRAMICHI SUB-ZONE
ELMTREE SUB-ZONE
NEW BRUNSWICK
GP
FREDERICTON SUB-ZONE
LUBEC
BELLE ISLE FAULT
PRINCE EDWARD ISLAND
VARISCAN FRONT
NOVA SCOTIA
COBEQUID-CHEDABUCTO FAULT
ASPY FAULT
CAPE BRETON ISLAND
GULF OF ST. LAWRENCE
NORTHWESTERN MARGINAL ZONE
SOUTHEASTERN MARGINAL ZONE
HUMBER ARM
HARE BAY
FAULT
BURLINGTON PENINSULA
NOTRE DAME SUB-ZONE
EXPLOITS SUB-ZONE
CABOT
REACH
FAULT
BOTWOOD SUB-ZONE
NEWFOUNDLAND
CAPE RAY FAULT
HERMITAGE BAY
FAULT
DOVER
ATLANTIC OCEAN
0 100 200 300 400 500 km
MAJOR FAULTS AND/OR SUB-ZONE BOUNDARIES
BOUNDARY OF CARBONIFEROUS COVER
T TRIASSIC
C CARBONIFEROUS
OPHIOLITES AND RELATED ROCKS
NW MARGINAL ZONE
CAMBRIAN MIDDLE ORDOVICIAN AUTOCHTHONOUS ROCKS OF NORTHWEST MARGINAL ZONE
ALLOCHTHONOUS CAMBRIAN-MIDDLE ORDOVICIAN OF NORTHWEST MARGINAL ZONE
LATE PRECAMBRIAN TO CAMBRO-ORDOVICIAN OF FLEUR DE LYS AND EQUIVALENTS — V VOLCANICS
CAMBRIAN-DEVONIAN OF AXIAL ZONE AND MIDDLE ORDOVICIAN TO DEVONIAN OF NORTHWEST MARGINAL ZONE
SE MARGINAL ZONE
M LOWER PALAEOZOIC OF THE MEGUMA TROUGH
LOWER PALAEOZOIC OF THE AVALONIAN TERRANE
DEFORMED ROCKS OF THE GANDER GROUP AND EQUIVALENTS
LATE PRECAMBRIAN OF THE AVALONIAN TERRANE
PRE-APPALACHIAN BASEMENT

FIGURE 2. Map of the Northern Appalachians in Canada showing the subdivisions into zones and subzones. Rocks in Quebec shown as Fleur de Lys equivalents probably do not show pre-Middle Ordovician deformation and metamorphism. Intrusive rocks are omitted. G.P. = Grand Pitch Formation (after Kennedy 1979).

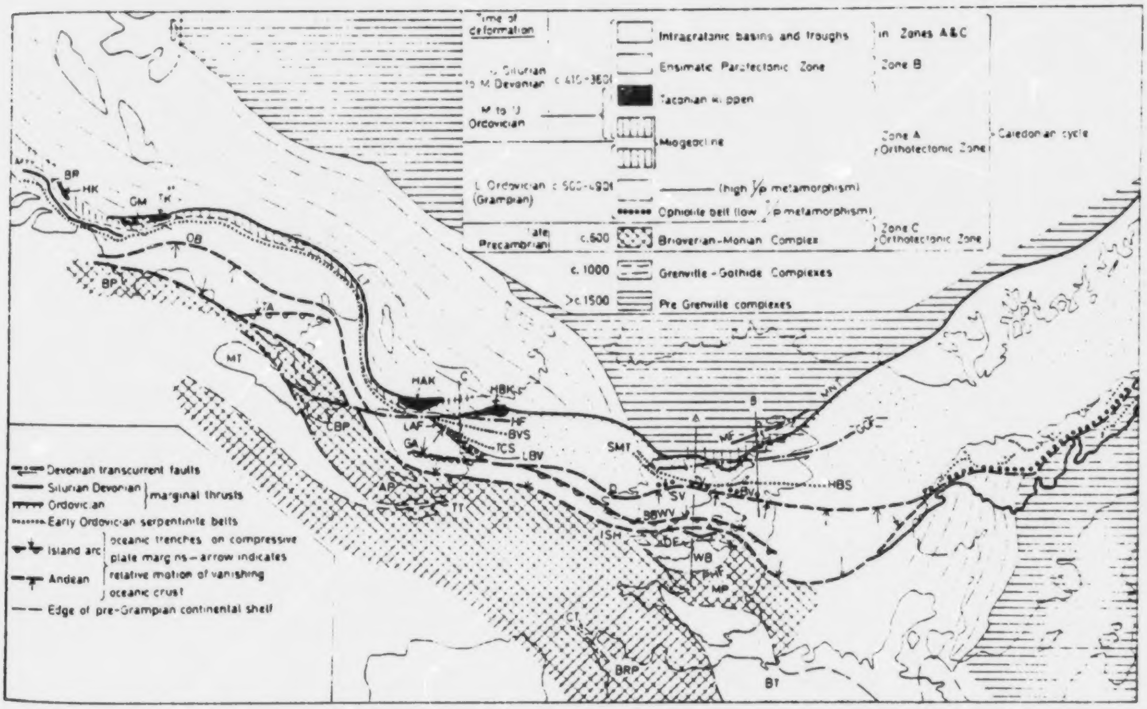

Time of deformation
Silurian to M. Devonian c. 415-360
M to U Ordovician
L Ordovician c 500-480 (Grampian)
Late Precambrian c.600
c. 1000
>c.1500
Intracratonic basins and troughs
Ensimatic Paratectonic Zone
Taconian klippen
Miogeocline
(high T/p metamorphism)
Ophiolite belt (low T/p metamorphism)
Brioverian-Monian Complex
Grenville-Gothide Complexes
Pre Grenville complexes
in Zones A&C
Zone B
Zone A Orthotectonic Zone
Zone C Orthotectonic Zone
Caledonian cycle
Devonian transcurrent faults
Silurian Devonian
Ordovician
marginal thrusts
Early Ordovician serpentinite belts
Island arc
Andean
oceanic trenches on compressive plate margins – arrow indicates relative motion of vanishing oceanic crust
Edge of pre-Grampian continental shelf
BP
HK
GM
TK
OB
BP
TA
MT
CBP
HAK
HBK
C
LAF
HF
BVS
TCS
LBV
GA
AP
TT
SMT
A
B
MNT
GGF
D
SV
TV
HBS
BBWV
ISH
DF
WB
PHF
MP
CT
BRP
BT

FIGURE 3. Strutural zones of the Appalachian/Caledonian orogen. AP = Avalon Platform; BBWV = Borrowdale, Balbriggan, Waterford Volcanic lineament; BP = Boston Platform; BR = Blue Ridge; BRP = Breton Platform; BT = Brabant Trough; BV = Ballantrae Volcanics; BVS = Baie Verte Serpentinite; CBP = Cape Breton Platform; CT = Crozon Trough; D = Dingle; DF = Dinorwic Fault; GA = Gander Volcanic lineament; GGF = Great Glen Fault; GM Green Mts.; HAK = Humber Arm Klippe; HBK = Hare Bay Klippe; HBS = Highland Boundary Serpentinite; HF = Hampden Fault; HK = Hamburg Klippe; ISH = Irish Sea Horst; LAF = Luke Arm Fault; LBV = Lushs Bight Volcanics; LT = Logans Thrust; MF = Minch Fault; MP = Midland Platform; MNT = Moine Thrust; MT = Meguma Trough; MTT = Martic Thrust; OB = Oliverian Belt; PHF = Pontesford Hill Fault; SMT = South Mayo Trough; SV = Strokestown Volcanics; TA = Tetagouche Volcanic lineament; TCS = Tilt Cove Serpentinite; TK = Taconic Klippe; TT = Trinity Trough; TV = Tyrone Volcanics; WB = Welsh Basin (after Dewey 1969).

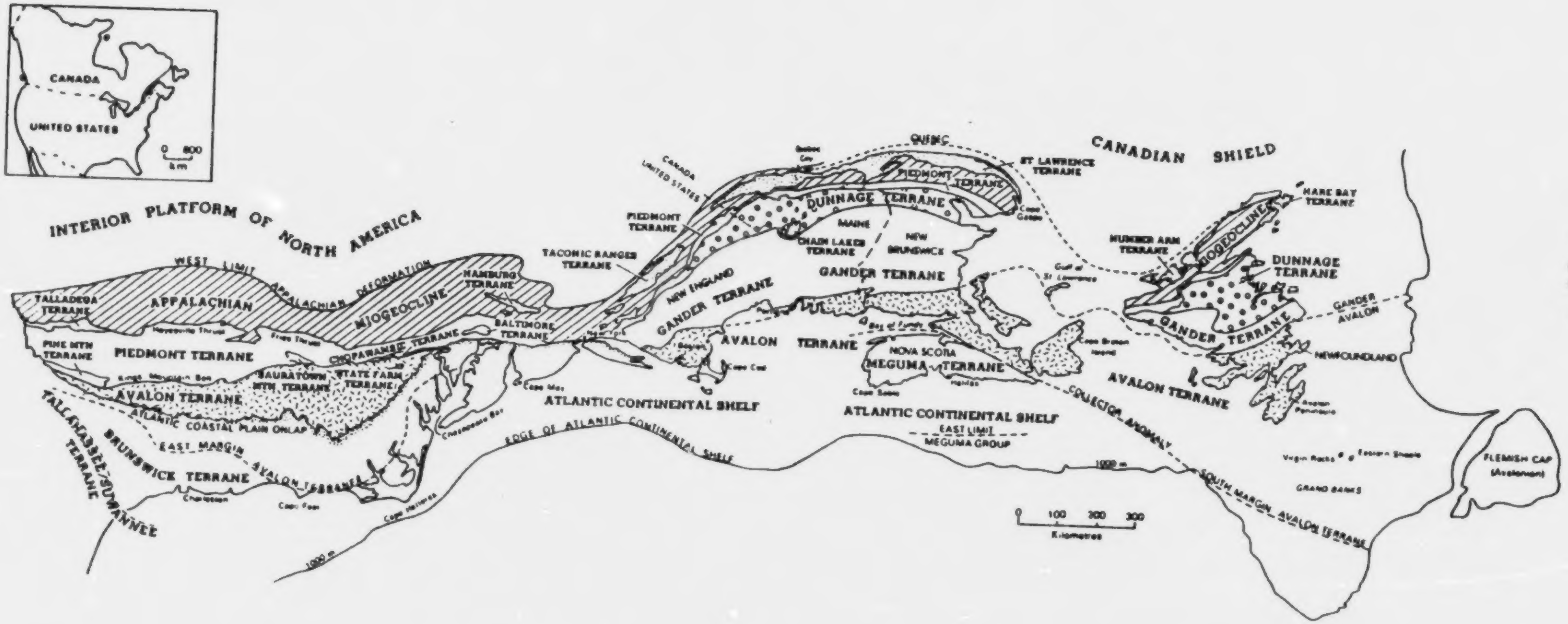

CANADA
UNITED STATES
0 800
km
INTERIOR PLATFORM OF NORTH AMERICA
WEST LIMIT APPALACHIAN DEFORMATION
TALLADEGA TERRANE
APPALACHIAN
MIOGEOCLINE
HAMBURG TERRANE
BALTIMORE TERRANE
PINE MTN TERRANE
PIEDMONT TERRANE
CHOPAWAMSIC TERRANE
SAURATOWN MTN TERRANE
STATE FARM TERRANE
AVALON TERRANE
ATLANTIC COASTAL PLAIN ONLAP
EAST MARGIN AVALON TERRANE
BRUNSWICK TERRANE
TALLAHASSEE/SUWANNEE TERRANE
Charleston
Cape Fear
Cape Hatteras
Chesapeake Bay
Cape May
New York
1000 m
EDGE OF ATLANTIC CONTINENTAL SHELF
ATLANTIC CONTINENTAL SHELF
TACONIC RANGES TERRANE
PIEDMONT TERRANE
CANADA
UNITED STATES
NEW ENGLAND
GANDER TERRANE
Boston
Cape Cod
AVALON TERRANE
QUEBEC
PIEDMONT TERRANE
ST LAWRENCE TERRANE
DUNNAGE TERRANE
Cape Gaspe
MAINE
CHAIN LAKES TERRANE
NEW BRUNSWICK
GANDER TERRANE
Bay of Fundy
NOVA SCOTIA
MEGUMA TERRANE
Halifax
Cape Sable
ATLANTIC CONTINENTAL SHELF
EAST LIMIT
MEGUMA GROUP
Gulf of St Lawrence
Cape Breton Island
COLLECTOR ANOMALY
CANADIAN SHIELD
HUMBER ARM TERRANE
MIOGEOCLINE
HARE BAY TERRANE
DUNNAGE TERRANE
GANDER TERRANE
GANDER
AVALON
NEWFOUNDLAND
AVALON TERRANE
Avalon Peninsula
Virgin Rocks
Eastern Shoals
GRAND BANKS
FLEMISH CAP
(Avalonian)
1000 m
SOUTH MARGIN AVALON TERRANE
0 100 200 300
Kilometres

FIGURE 5. Suspect terranes of Appalachian origin (after Williams and Hatcher 1982).

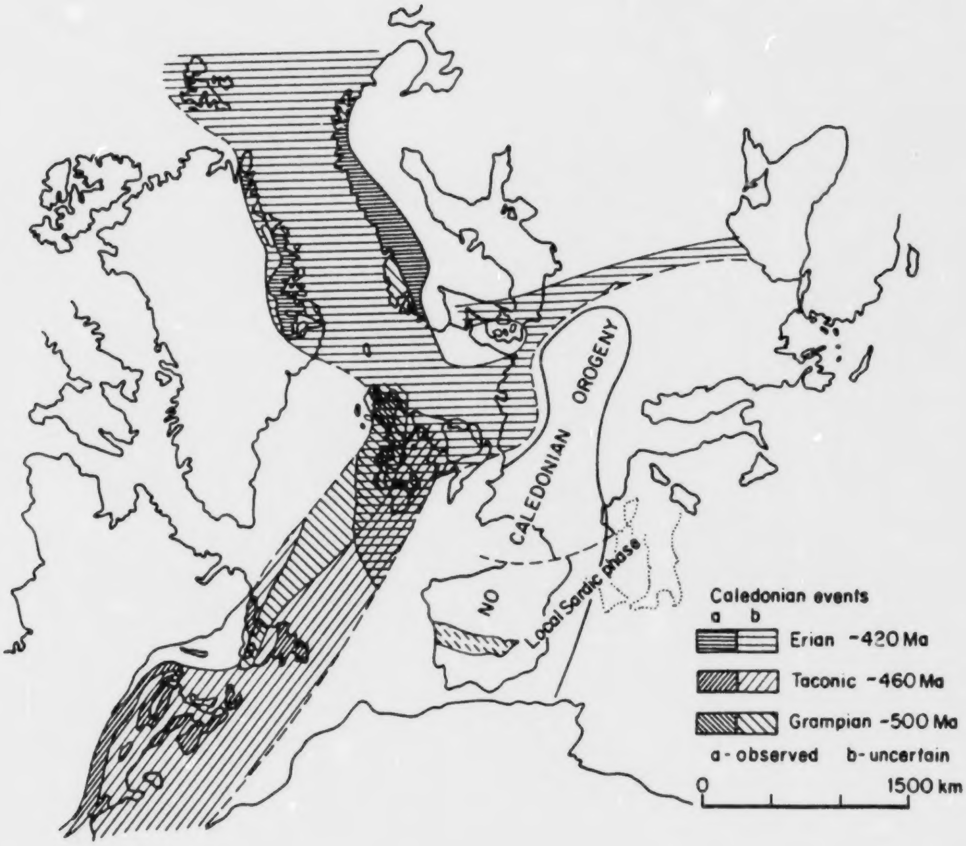

CALEDONIAN OROGENY
NO
Local Sardic phase
Caledonian events
a b
Erian -420 Ma
Taconic -460 Ma
Grampian -500 Ma
a - observed b - uncertain
0
1500 km

FIGURE 6. The distribution of the three main tectonic events of Caledonian age in the North Atlantic region (after Windley 1982).

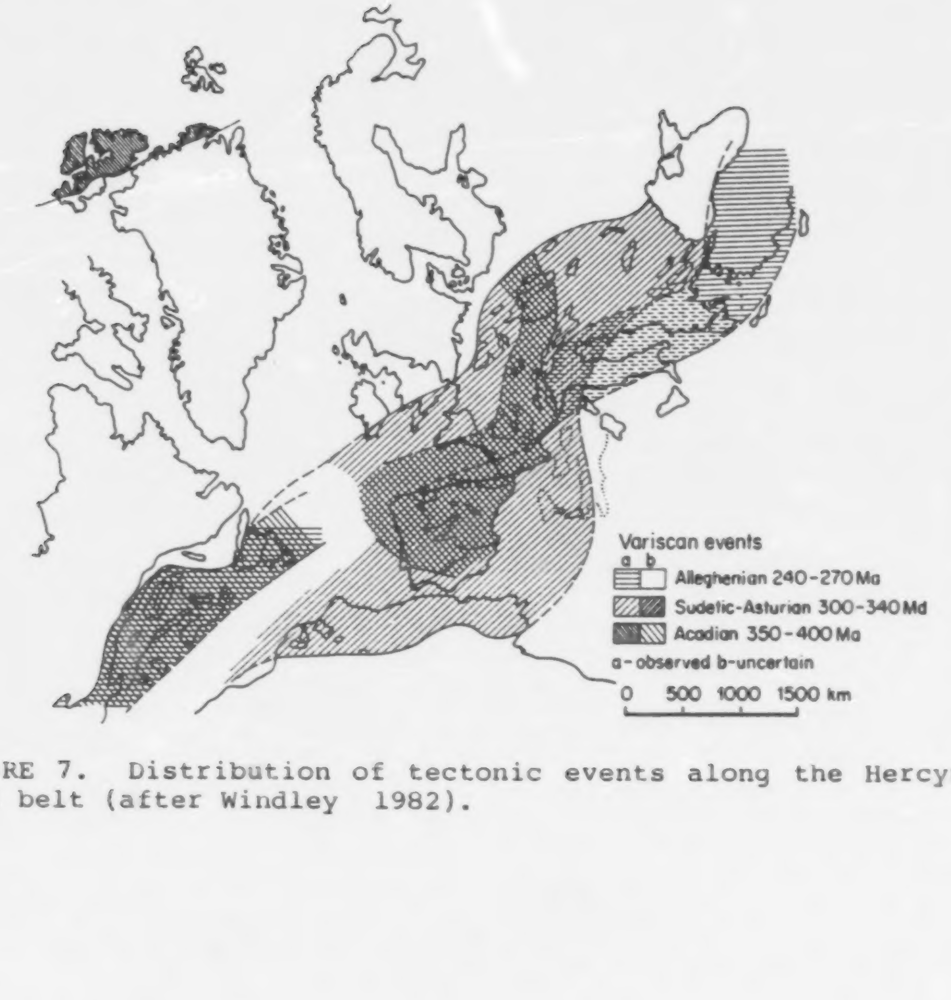

Variscan events
a b
Alleghenian 240-270 Ma
Sudetic-Asturian 300-340 Md
Acadian 350-400 Ma
a-observed b-uncertain
0 500 1000 1500 km

FIGURE 7. Distribution of tectonic events along the Hercynian fold belt (after Windley 1982).

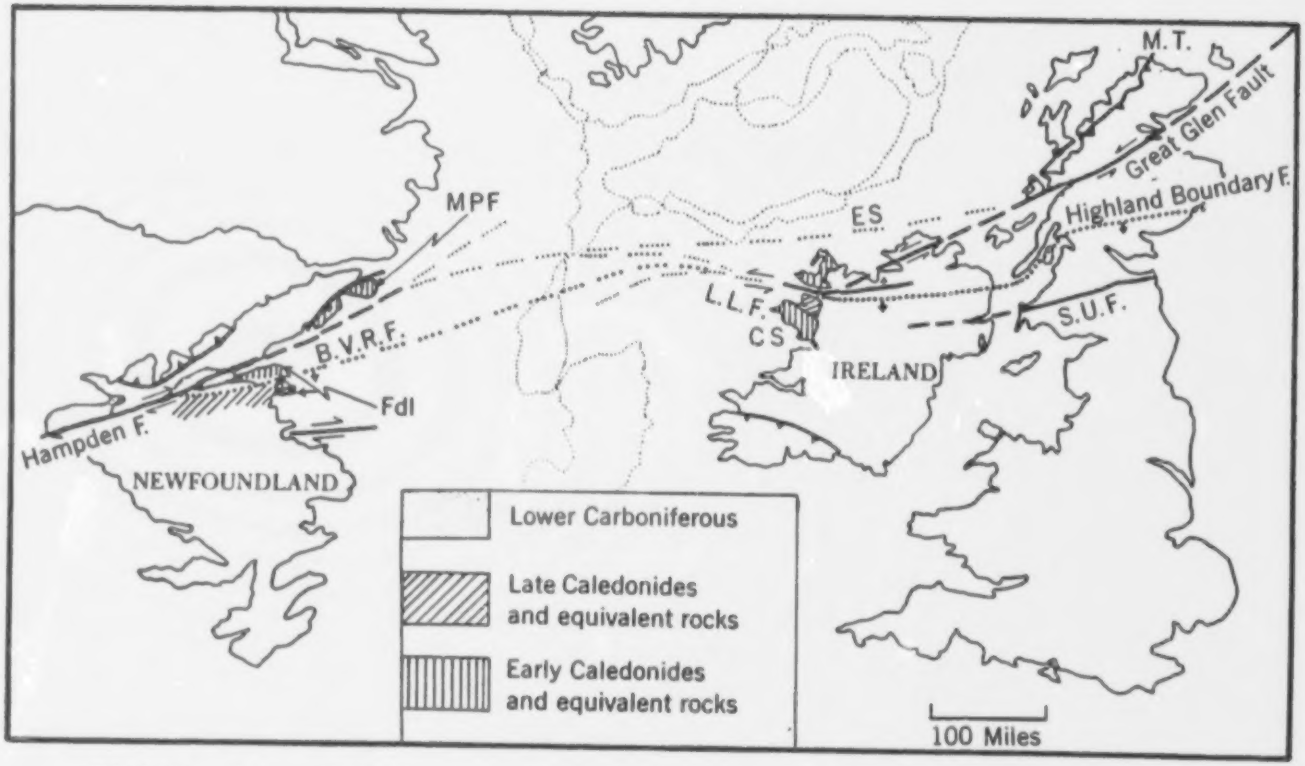

M.T.
Great Glen Fault
Highland Boundary F.
ES
MPF
L.L.F.
CS
S.U.F.
B.V.R.F.
IRELAND
Fdl
Hampden F.
NEWFOUNDLAND
Lower Carboniferous
Late Caledonides and equivalent rocks
Early Caledonides and equivalent rocks
100 Miles

FIGURE 8. Possible continuation of major structures from Ireland to Newfoundland. Continental reconstruction to 500-fm contour is based on Bullard et al. (1965). B.V.R.F. = Baie Verte Road fault; CS = Connemara schist; ES = Erris schist; Fdl = Fleur de Lys Group; L.L.F. = Leannan-Leck fault; MPF = Maiden Point Formation; M.T. = Moine thrust; S.U.F. = Southern Uplands fault (after Phillips et al. 1969).

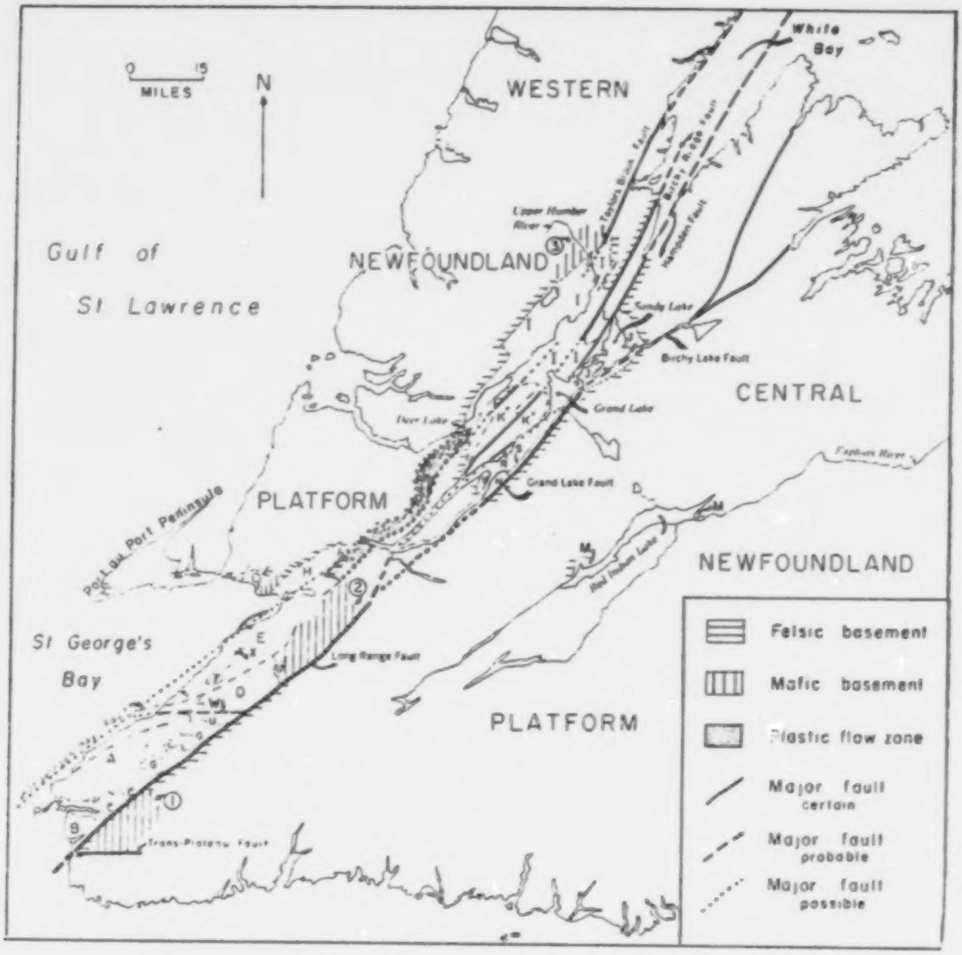

0 15
MILES
N
WESTERN
White Bay
Gulf of
St Lawrence
NEWFOUNDLAND
Upper Humber River
Taylors Brook Fault
Birchy Ridge Fault
Hampden Fault
Sandy Lake
Birchy Lake Fault
CENTRAL
Deer Lake
Grand Lake
Grand Lake Fault
Exploits River
PLATFORM
Port au Port Peninsula
Red Indian Lake
NEWFOUNDLAND
St George's
Bay
Long Range Fault
PLATFORM
Trans-Plateau Fault
①
②
③
A
B
C
D
E
G
H
I
K
M
O
S
U
W
X
Felsic basement
Mafic basement
Plastic flow zone
Major fault certain
Major fault probable
Major fault possible

FIGURE 9. Distribution of Carboniferous rocks in Newfoundland, Canada. Basins of Carboniferous strata are outlined by either horizontal or vertical lines. Carboniferous rock units are outlined by finely dotted lines. Locality J = "Howley Beds"; I, N, S, V = Deer Lake Group; B, C, D, O = Barachois Group; P, G, E, H = Codroy Group; U = Codroy border facies; A, F, K, L = Anguille Group; M = unnamed formation; W = east-west fault; X = region of pre-Carboniferous basement within the basin. Regions (1), (2), and (3), and small area between localities O and H, are areas of mafic basement rock discussed in text (after Belt 1969).

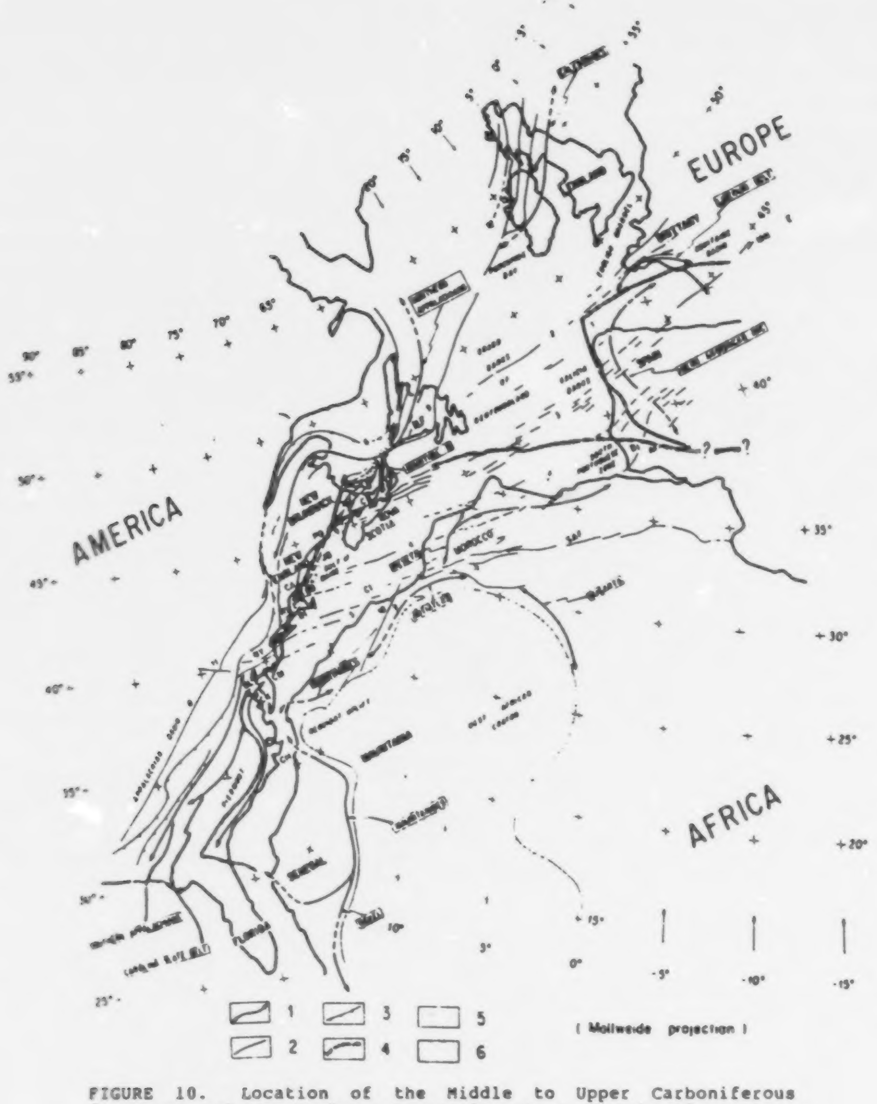

EUROPE
AMERICA
AFRICA
NOVA SCOTIA
MOROCCO
FLORIDA
SAF
?——?
90°
85°
80°
75°
70°
65°
55°
50°
45°
40°
35°
30°
25°
+40°
+35°
+30°
+25°
+20°
15°
10°
5°
0°
-5°
-10°
-15°
1
2
3
4
5
6
(Mollweide projection)

FIGURE 10. Location of the Middle to Upper Carboniferous fractures and the Gondwana-Laurussia suture (hatchured zone) on a Permo-Triassic continental configuration. Ar = Aracena; AV = Avalon; BB = Boston Basin; Bj = Beja; BL = Baltimore; CA = Cape Anne; CB = Cobequid Mountains; CH = Chesapeake Bay; CI = Canary Islands; CM = Cape May; E = Estérel; JB = Jeffreys Basin; NF = Newfoundland; MN = Montagne Noire; NY = New York State;PQ = Passamaquoddy Bay; RI = Rhode Island; SAF = South Atlas Fault. Explanation of legend: 1 = axes of the orogenic belts; 2 = faults; 3 = thrusts; 4 = suture; 5 = Carboniferous basin or rift deposits; 6 = the West African craton (after Lefort and van der Voo 1981).

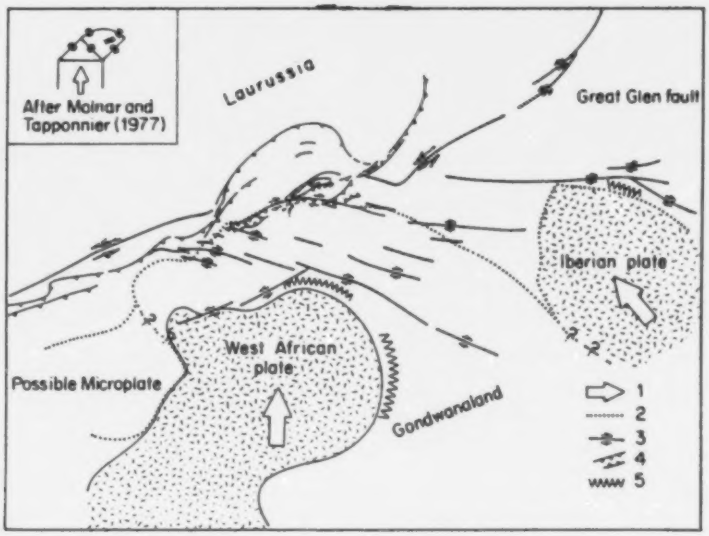

After Molnar and Tapponnier (1977)
Laurussia
Great Glen fault
Iberian plate
West African plate
Possible Microplate
Gondwanaland
1
2
3
4
5

FIGURE 11. Structural and kinematic interpretation of the Middle to Upper Carboniferous motions during and after the Gondwana-Laurussia collision. Explanation: 1 = possible motion of indenting plates during Carboniferous time; 2 = suture; 3 = strike-slip faults; 4 = grabens; 5 = fold belts active during the Late Carboniferous (after Windley 1982).

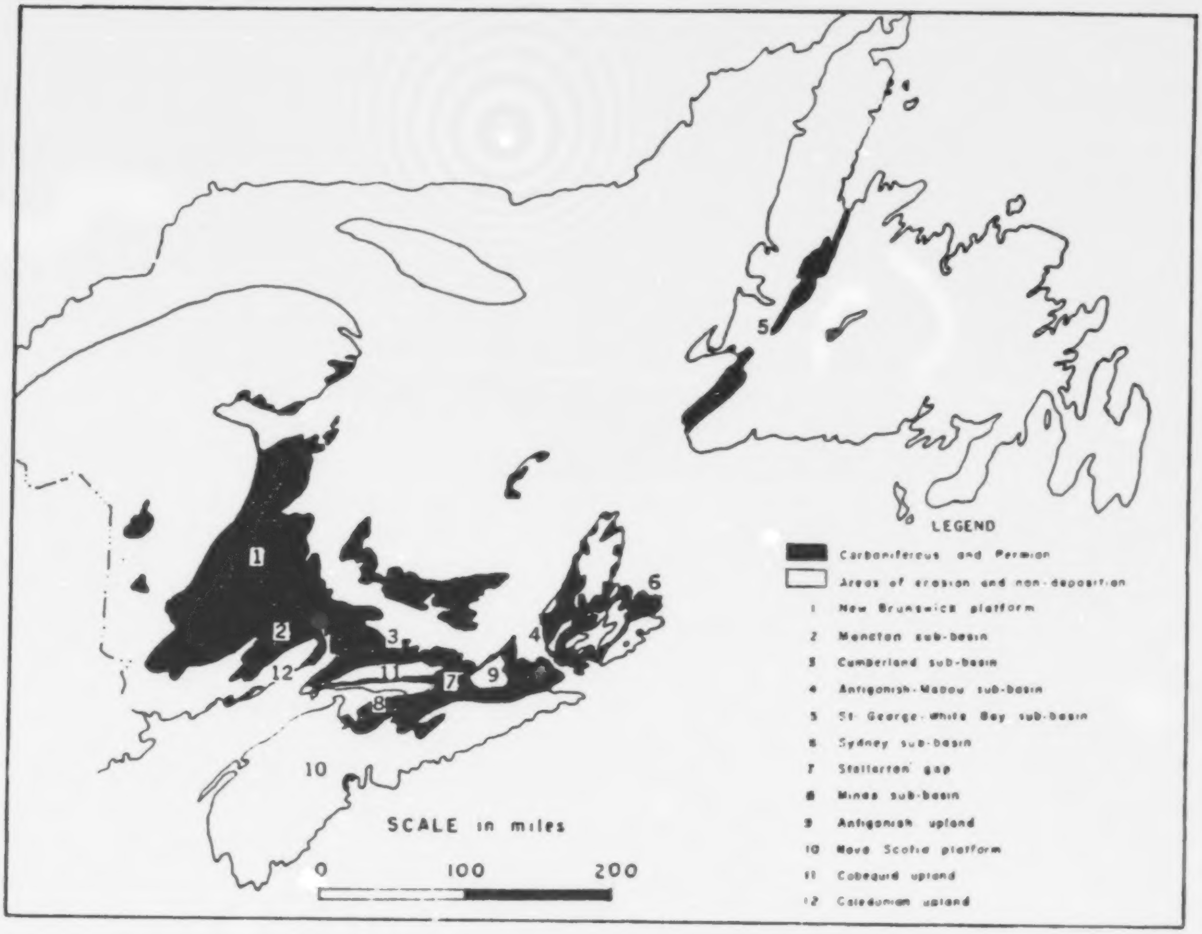

1
2
3
4
5
6
7
8
9
10
11
12
SCALE in miles
0
100
200
LEGEND
Carboniferous and Permian
Areas of erosion and non-deposition
1 New Brunswick platform
2 Moncton sub-basin
3 Cumberland sub-basin
4 Antigonish-Mabou sub-basin
5 St George-White Bay sub-basin
6 Sydney sub-basin
7 Stellarton gap
8 Minas sub-basin
9 Antigonish upland
10 Nova Scotia platform
11 Cobequid upland
12 Caledonian upland

FIGURE 12. Distribution of Carboniferous and Permian rocks in the Atlantic Provinces (after Kelley 1967).

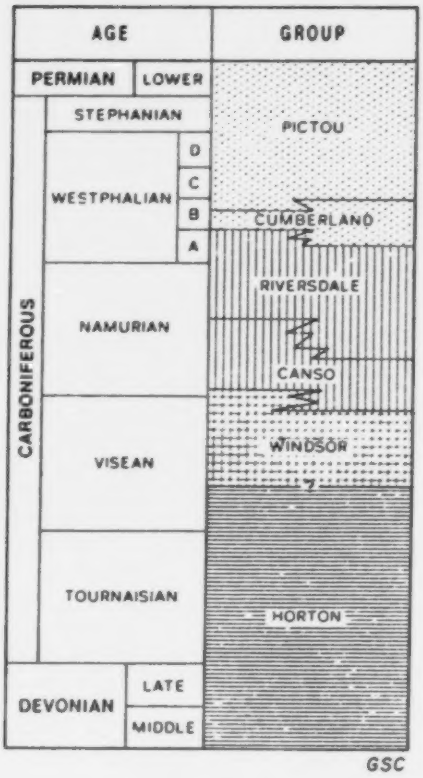

AGE
GROUP
PERMIAN
LOWER
STEPHANIAN
D
C
B
A
WESTPHALIAN
CARBONIFEROUS
NAMURIAN
VISEAN
TOURNAISIAN
DEVONIAN
LATE
MIDDLE
PICTOU
CUMBERLAND
RIVERSDALE
CANSO
WINDSOR
?
HORTON
GSC

FIGURE 13. Stratigraphic subdivisions and ages of Upper Paleozoic rocks of eastern Canada (after Howie and Barss 1975).

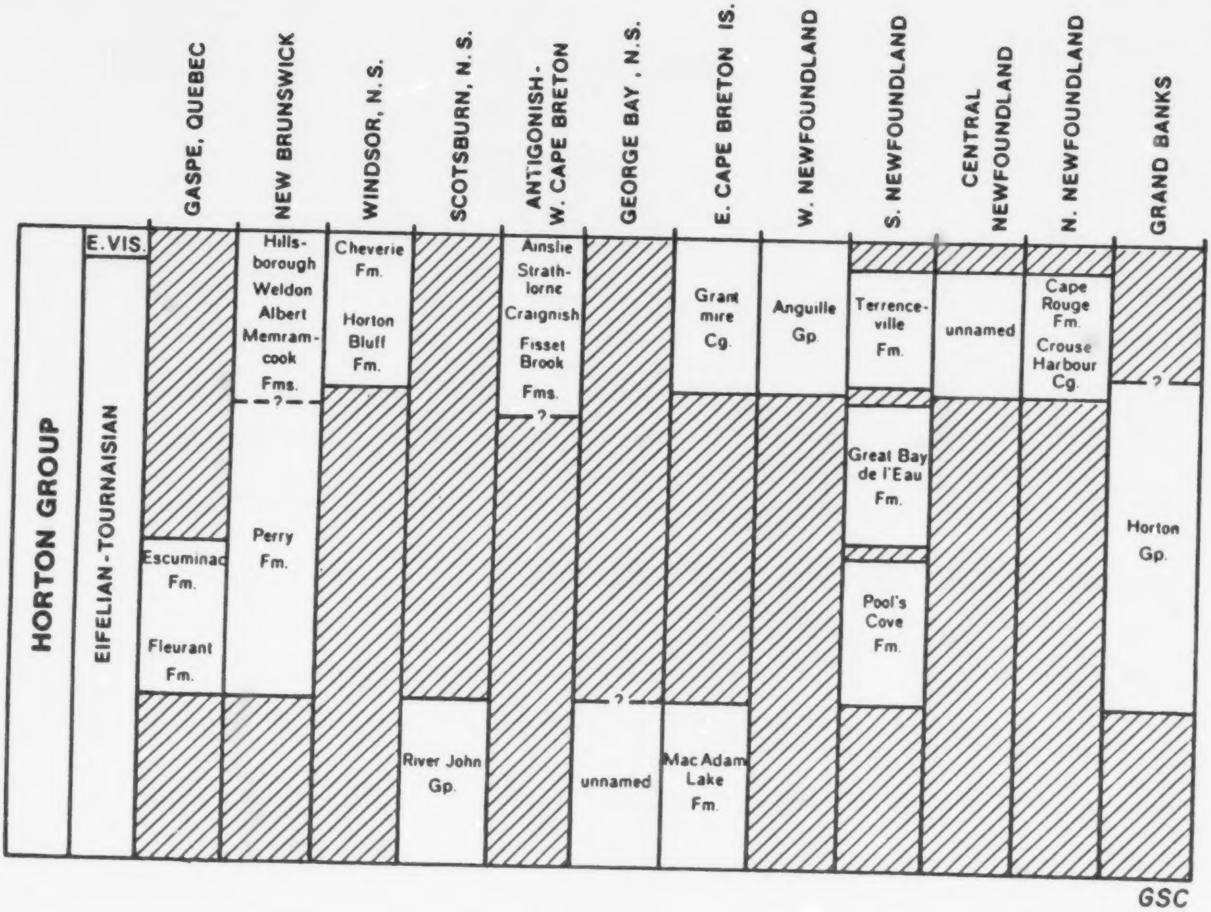

HORTON GROUP
E.VIS.
EIFELIAN-TOURNAISIAN
GASPE, QUEBEC
Escuminac Fm.
Fleurant Fm.
NEW BRUNSWICK
Hills-borough
Weldon
Albert
Memram-cook
Fms.
?
Perry Fm.
WINDSOR, N.S.
Cheverie Fm.
Horton Bluff Fm.
SCOTSBURN, N.S.
River John Gp.
ANTIGONISH-W. CAPE BRETON
Ainslie
Strath-lorne
Craignish
Fisset Brook
Fms.
?
GEORGE BAY, N.S.
?
unnamed
E. CAPE BRETON IS.
Grant mire Cg.
MacAdam Lake Fm.
W. NEWFOUNDLAND
Anguille Gp.
S. NEWFOUNDLAND
Terrence-ville Fm.
Great Bay de l'Eau Fm.
Pool's Cove Fm.
CENTRAL NEWFOUNDLAND
unnamed
N. NEWFOUNDLAND
Cape Rouge Fm.
Crouse Harbour Cg.
GRAND BANKS
?
Horton Gp.
GSC

FIGURE 14. Correlatives of the Horton Group (after Howie and Barss 1974).

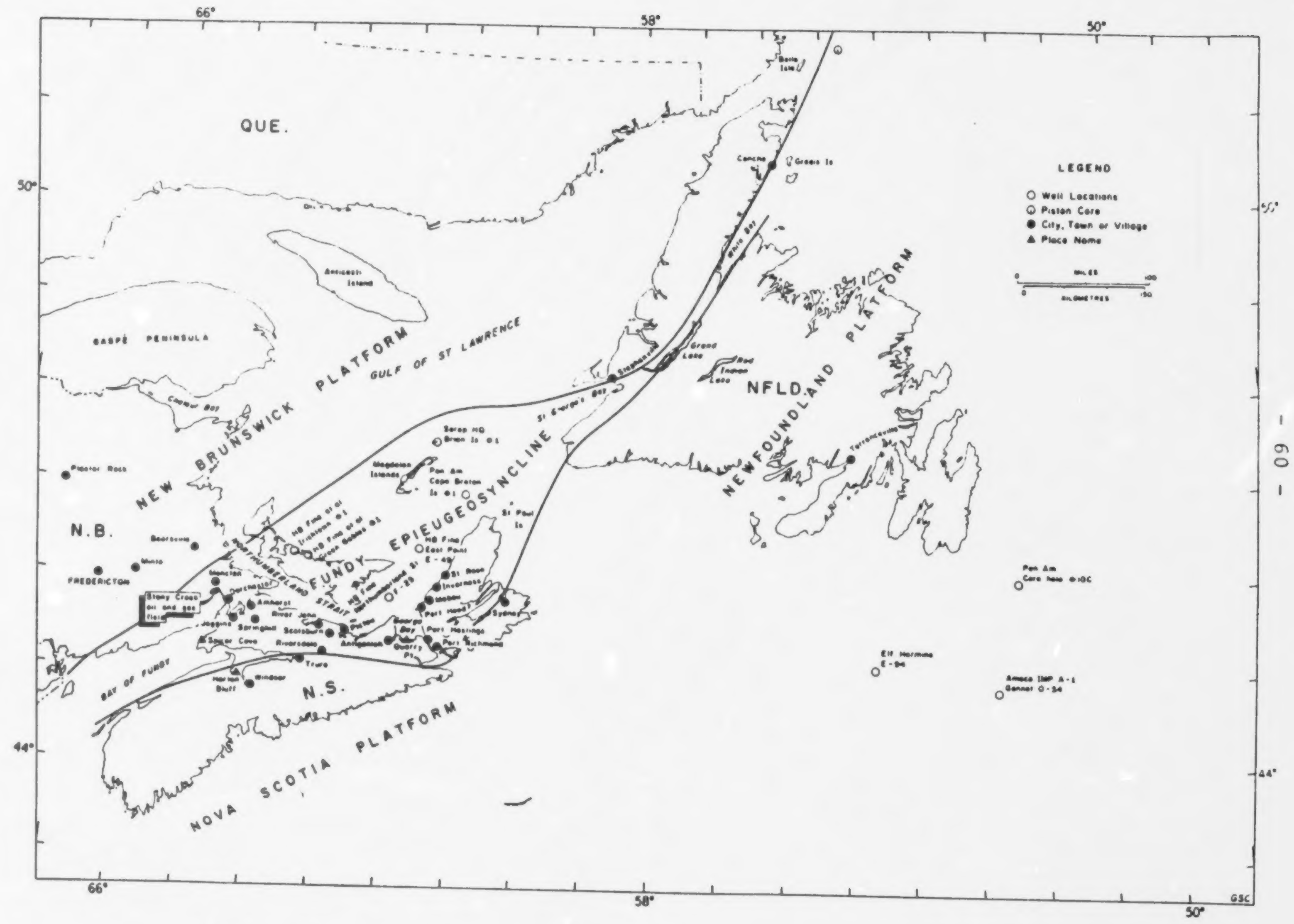

66°
58°
50°
44°
GSC
QUE.
N.B.
N.S.
NFLD.
NEW BRUNSWICK PLATFORM
GULF OF ST LAWRENCE
GASPÉ PENINSULA
Anticosti Island
Chaleur Bay
FREDERICTON
Plaster Rock
Minto
Moncton
Stony Creek oil and gas field
Dorchester
Amherst
Joggins
Springhill
River John
Scotsburn
Pictou
Antigonish
Sucker Cove
Riversdale
Truro
Horton Bluff
Windsor
BAY OF FUNDY
NORTHUMBERLAND STRAIT
FUNDY EPIEUGEOSYNCLINE
Magdalen Islands
Pan Am Cape Breton Is. 0-1
St Paul Is
St Rose
Inverness
Mabou
Port Hood
George Bay
Port Hastings
Port Richmond
Quarry Pt.
Sydney
St George's Bay
Stephenville
Grand Lake
Red Indian Lake
White Bay
Canche
Groais Is
Belle Isle
NEWFOUNDLAND PLATFORM
NOVA SCOTIA PLATFORM
Pan Am Cora hole 0-0C
Elf Hermine E-94
Amoco IMP A-1 Gannet O-54
LEGEND
○ Well Locations
◎ Piston Core
● City, Town or Village
▲ Place Name
0 MILES 100
0 KILOMETRES 150

FIGURE 16. Location map of southeastern Canada (after Howie and Barss 1974).

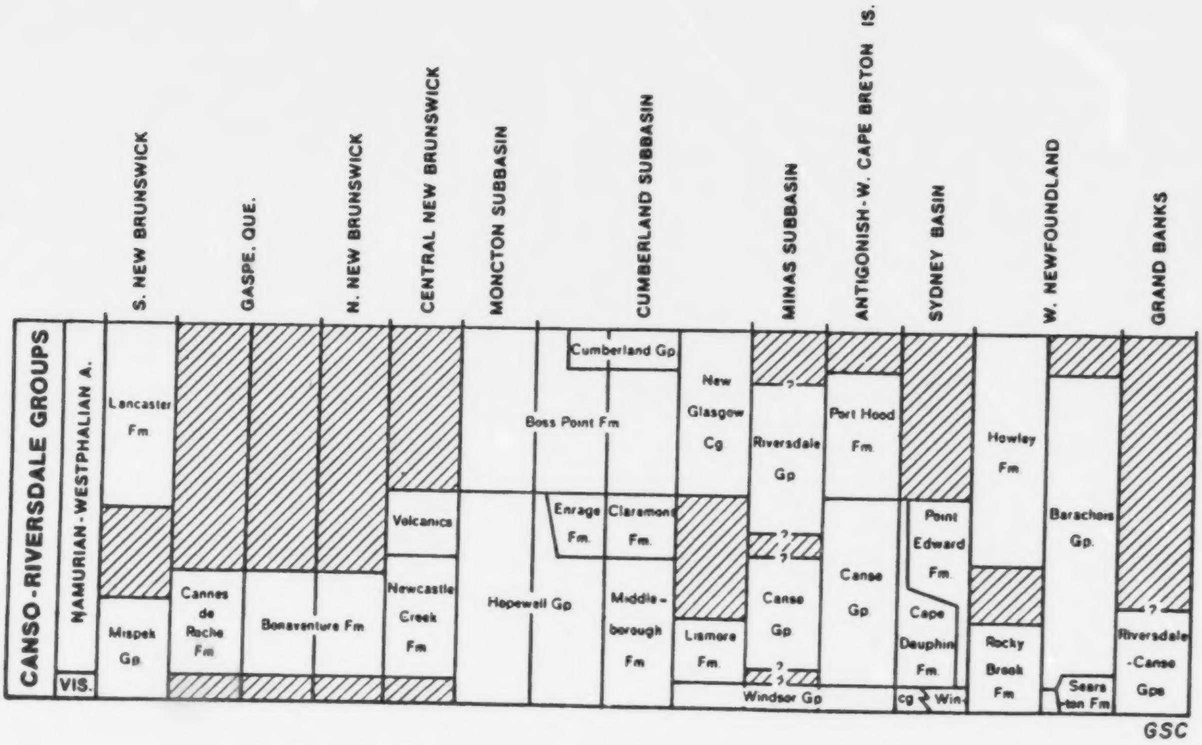

CANSO-RIVERSDALE GROUPS
NAMURIAN-WESTPHALIAN A.
VIS.
S. NEW BRUNSWICK
GASPE, QUE.
N. NEW BRUNSWICK
CENTRAL NEW BRUNSWICK
MONCTON SUBBASIN
CUMBERLAND SUBBASIN
MINAS SUBBASIN
ANTIGONISH-W. CAPE BRETON IS.
SYDNEY BASIN
W. NEWFOUNDLAND
GRAND BANKS
Lancaster Fm
Mispek Gp
Cannes de Roche Fm
Bonaventure Fm
Volcanics
Newcastle Creek Fm
Cumberland Gp
Boss Point Fm
Enrage Fm.
Claremont Fm.
Hopewell Gp
Middle-borough Fm
New Glasgow Cg
Lismore Fm.
Riversdale Gp
Canso Gp
Windsor Gp
Port Hood Fm.
Canso Gp
Point Edward Fm.
Cape Dauphin Fm.
cg
Win-
Howley Fm
Rocky Brook Fm
Barachois Gp.
Searston Fm
Riversdale-Canso Gps
?
GSC

FIGURE 18. Correlatives of the Canso-Riversdale groups (after Howie and Barss 1974).

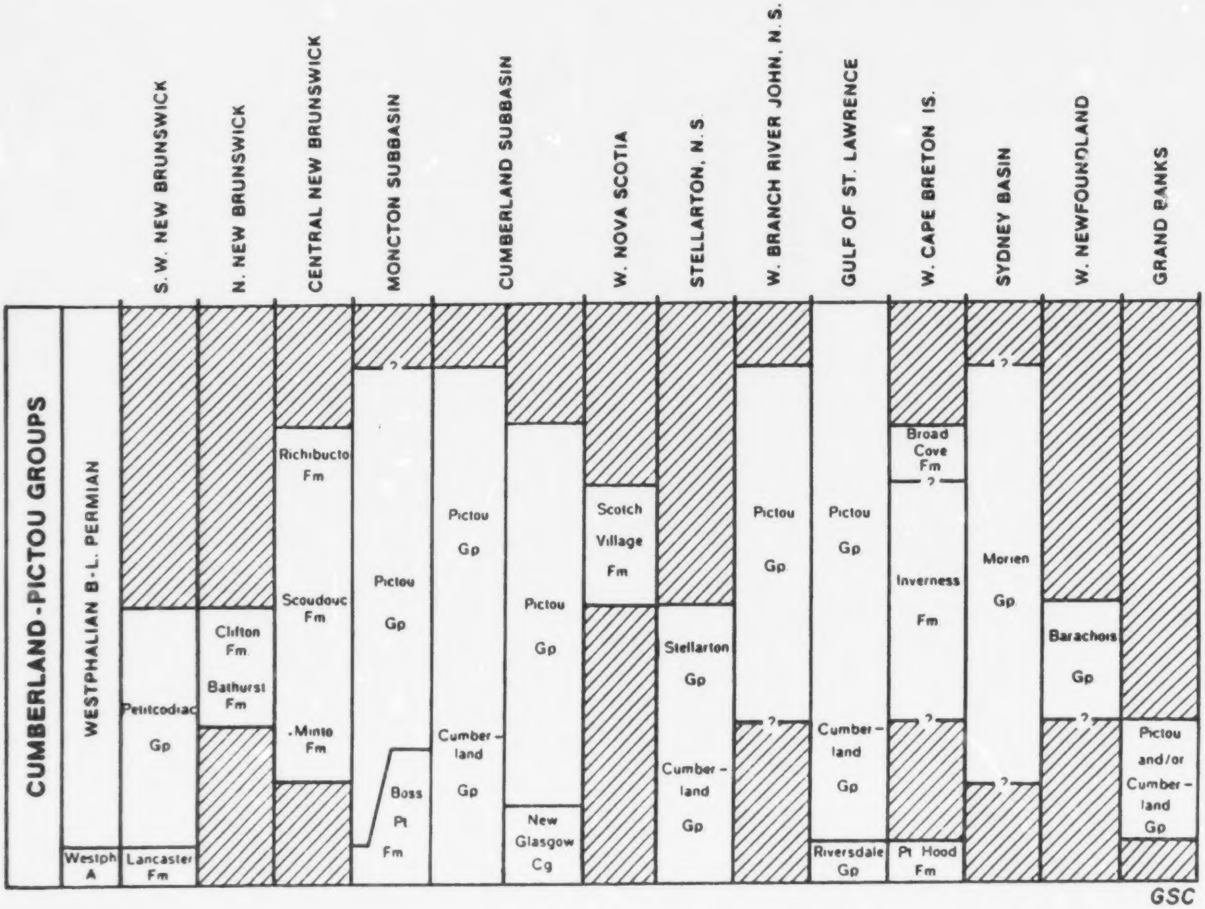

CUMBERLAND-PICTOU GROUPS
WESTPHALIAN B - L. PERMIAN
Westph A
S. W. NEW BRUNSWICK
Petitcodiac Gp
Lancaster Fm
N. NEW BRUNSWICK
Clifton Fm
Bathurst Fm
CENTRAL NEW BRUNSWICK
Richibucto Fm
Scoudouc Fm
Minto Fm
MONCTON SUBBASIN
Pictou Gp
Boss Pt Fm
CUMBERLAND SUBBASIN
Pictou Gp
Cumber - land Gp
Pictou Gp
New Glasgow Cg
W. NOVA SCOTIA
Scotch Village Fm
STELLARTON, N. S.
Stellarton Gp
Cumber - land Gp
W. BRANCH RIVER JOHN, N. S.
Pictou Gp
GULF OF ST. LAWRENCE
Pictou Gp
Cumber - land Gp
Riversdale Gp
W. CAPE BRETON IS.
Broad Cove Fm
Inverness Fm
Pt Hood Fm
SYDNEY BASIN
Morien Gp
W. NEWFOUNDLAND
Barachois Gp
GRAND BANKS
Pictou and/or Cumber - land Gp
?
GSC

FIGURE 20. Correlatives of the Cumberland-Pictou groups (after Howie and Barss 1974).

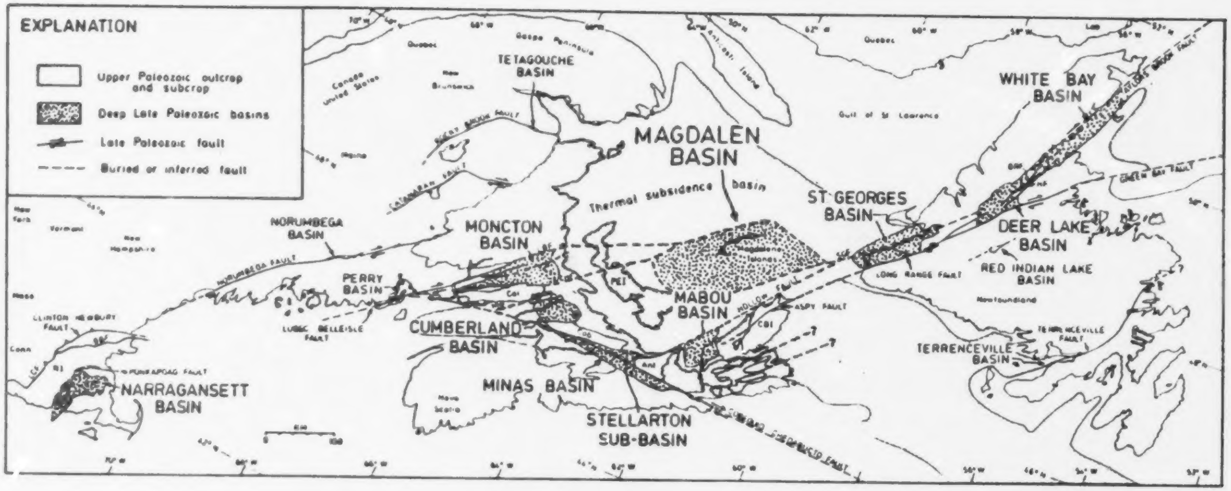

EXPLANATION
Upper Paleozoic outcrop and subcrop
Deep Late Paleozoic basins
Late Paleozoic fault
Buried or inferred fault
Quebec
Gaspe Peninsula
TETAGOUCHE BASIN
Canada
United States
New Brunswick
Maine
New York
Vermont
New Hampshire
Mass
Conn
CLINTON NEWBURY FAULT
RI
LCF
PONKAPOAG FAULT
NARRAGANSETT BASIN
NORUMBEGA BASIN
NORUMBEGA FAULT
PERRY BASIN
LUBEC BELLEISLE FAULT
MONCTON BASIN
CUMBERLAND BASIN
Cal
Cob
Ant
MINAS BASIN
Nova Scotia
STELLARTON SUB-BASIN
MAGDALEN BASIN
Thermal subsidence basin
Magdalene Islands
Anticosti Island
Gulf of St Lawrence
PEI
MABOU BASIN
HOLLOW FAULT
ASPY FAULT
CBI
ST GEORGES BASIN
LONG RANGE FAULT
WHITE BAY BASIN
GREEN BAY FAULT
DEER LAKE BASIN
RED INDIAN LAKE BASIN
Newfoundland
TERRENCEVILLE FAULT
TERRENCEVILLE BASIN
COBEQUID FAULT
KM
0
100
70° W
68° W
66° W
64° W
62° W
60° W
58° W
56° W
54° W
52° W
44° N
46° N
48° N
50° N

FIGURE 22. Late Paleozoic basins and faults in the northern Appalachians. Abbreviations used are as follows: CBI = Cape Breton Island; PEI = Prince Edward Island; RI = Rhode Island; Cal = Caledonia Massif; Cob = Cobequid Massif; Ant = Antigonish Massif; HF = Hampden fault; BRF = Birchy Ridge fault; HHF = Harvey-Hopewell fault; CHF = Clover Hill-Pollet River fault; PBF = Petitcodiac-Berry's Mills fault; LBF = Lubec-Belleisle fault; BBF = Bloddy Bluff fault; LCF = Lake Char fault. Many other faults are not shown. Composite Fundy Basin refers to the area of contiguous upper Paleozoic strata in New Brunswick, Nova Scotia, Prince Edward Island, southwestern Newfoundland, and the Gulf of St. Lawrence (after Bradley 1982).

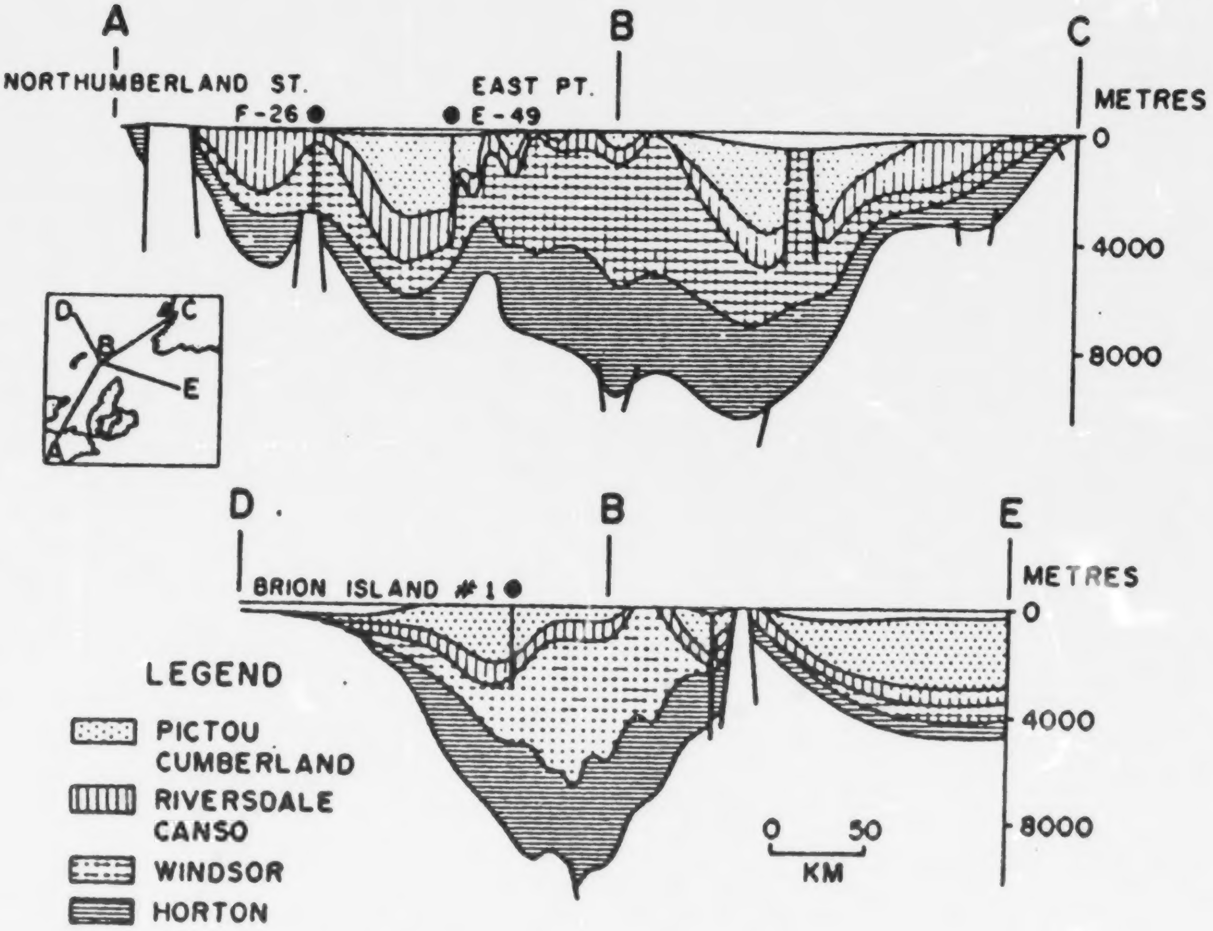

A
B
C
NORTHUMBERLAND ST.
EAST PT.
F-26
E-49
METRES
0
4000
8000
D
B
C
E
A
D
B
E
BRION ISLAND #1
METRES
0
4000
8000
LEGEND
PICTOU CUMBERLAND
RIVERSDALE CANSO
WINDSOR
HORTON
0
50
KM

FIGURE 23. Cross sections in Gulf of St. Lawrence (after Howie and Barss 1975).

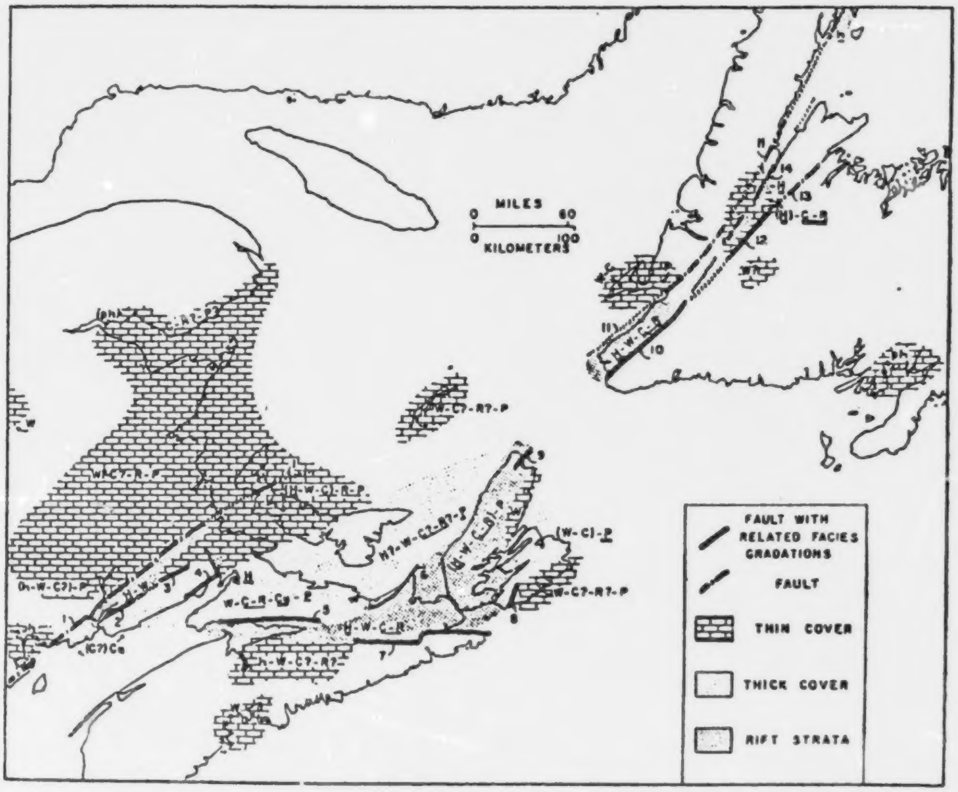

MILES
0
60
0
100
KILOMETERS
FAULT WITH RELATED FACIES GRADATIONS
FAULT
THIN COVER
THICK COVER
RIFT STRATA
W-C?-R-P
H-W-C)-R-P
H?-W-C?-R?-P
W-C?-R?-P
(W-C)-P
W-C?-R?-P
W-C-R-Cu-P
H-W-C-R
H-W-C?-R?
H-W-C-R
(H)-C-R
1
2
3
4
5
6
7
8
9
10
11
12
13
14

FIGURE 24. Carboniferous tectonic map of eastern Canada. "Thin cover" represents less than 1500 metres (5,000 feet) of undeformed strata; "thick cover" represents more than 1500 metres (5,000 feet) of undeformed strata; "rift strata" represents thick, highly deformed strata. H = Hortonian and pre-Hortonian; h = Hortonian; ph = pre-Hortonian (Late Devonian where shown); W = Windsorian; C = Cansoan; R = Riversdalian; Cu = Cumberlandian; P = Pictouan. Units in brackets are unconformably overlain by units to right of bracket symbol. Absence of underscoring means unit is thin; single underscoring means unit is moderately thick; double underscoring means unit is excessively thick. Numbered fault localities: 1 = Lubec-Belleisle; 2 = Clover Hill; 3 = Pollett-Caledonia; 4 = Harvey-Hopewell; 5 = Cobequid; 6 = Hollow; 7 = Guysborough; 8 = Grand River; 9 = Aspy; 10 = Long Range; 11 = St. George's Bay-Taylors Brook; 12 = Grand Lake; 13 = Birchy Lake; 14 = Birchy Ridge (after Belt 1968)

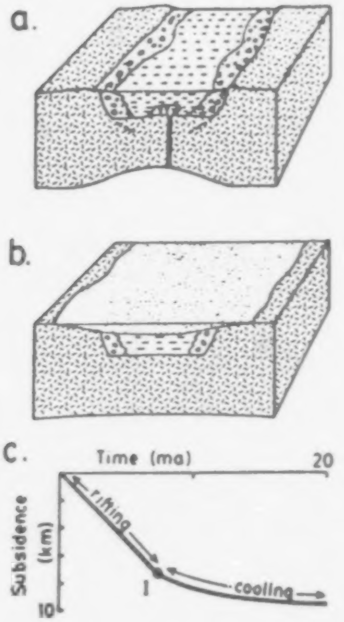


FIGURE 25. (a) Block diagram illustrating the initial stretching phase in an idealized rift. Growth faults control thickness and facies of rapidly deposited, immature clastics shed from local source areas. (b) Subsequent phase of thermal subsidence, which affects a wider area, but proceeds at a slower rate. Mature clastics are deposited farther from source areas. (c) Idealized subsidence curve of a basin formed as a result of stretching of the lithosphere by a factor of about B = 2. The inflection point of the curve, I = the initial subsidence (after Bradley 1982).

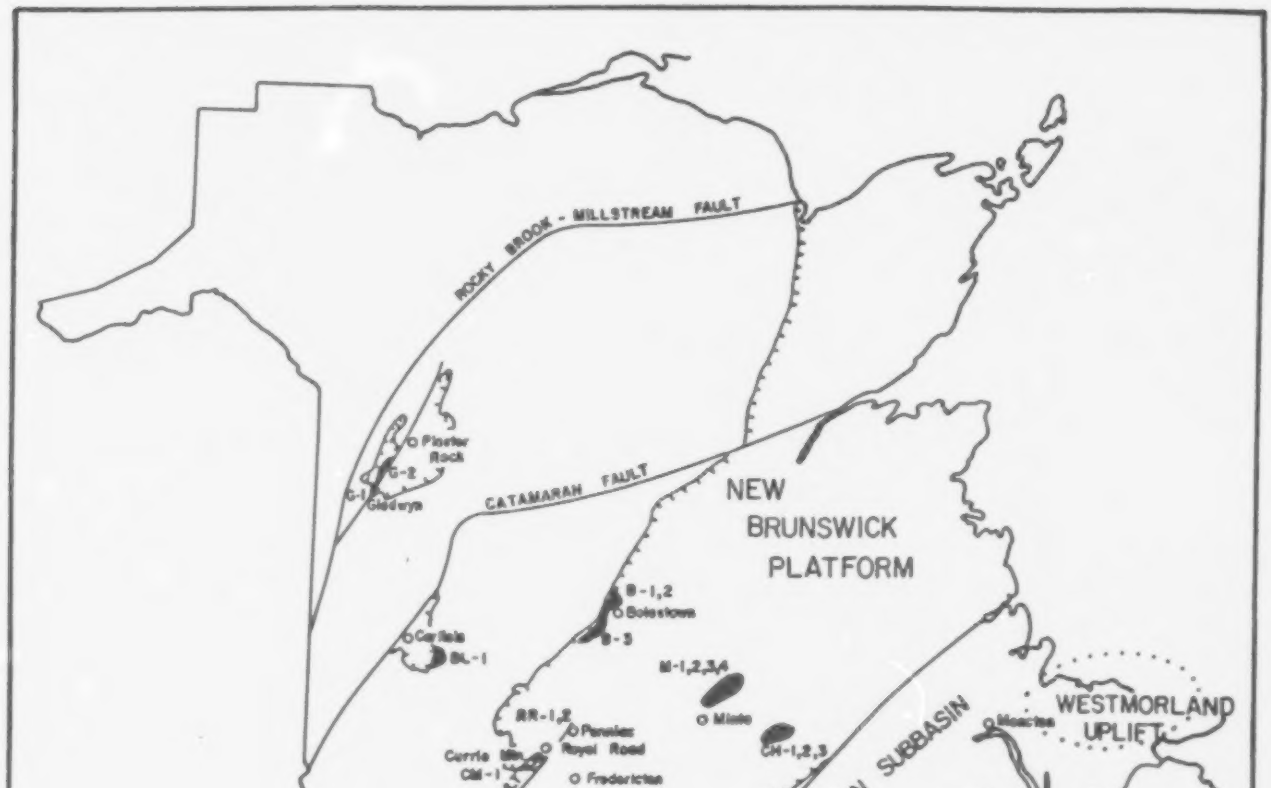

ROCKY BROOK - MILLSTREAM FAULT
O Plaster Rock
G-2
G-1
Gladwyn
CATAMARAN FAULT
NEW BRUNSWICK PLATFORM
B-1,2
O Boiestown
B-3
O Carlisle
BL-1
M-1,2,3,4
O Minto
CH-1,2,3
RR-1,2
O Penniac
O Royal Road
Currie Mtn.
CM-1
O Fredericton
Harvey
H-1
FREDERICTON FAULT
Queenstown
Q-1,2,3
O Hoyt
Mount Pleasant
SO-1
BELLEISLE FAULT
MONCTON SUBBASIN
O Moncton
WESTMORLAND UPLIFT
CUMBERLAND SUBBASIN
Scale
50 40 30 20 10 0 50 km
LEGEND
Carboniferous unconformity
Volcanic rocks
Q-2 Sample number
QUEBEC
Gulf of St. Lawrence
P.E.I.
NEW BRUNSWICK
MAINE
NOVA SCOTIA
Atlantic Ocean

FIGURE 26. Carboniferous paleogeographic elements of the Maritimes Basin in New Brunswick showing sample locations (after Fyffe and Barr, in press).

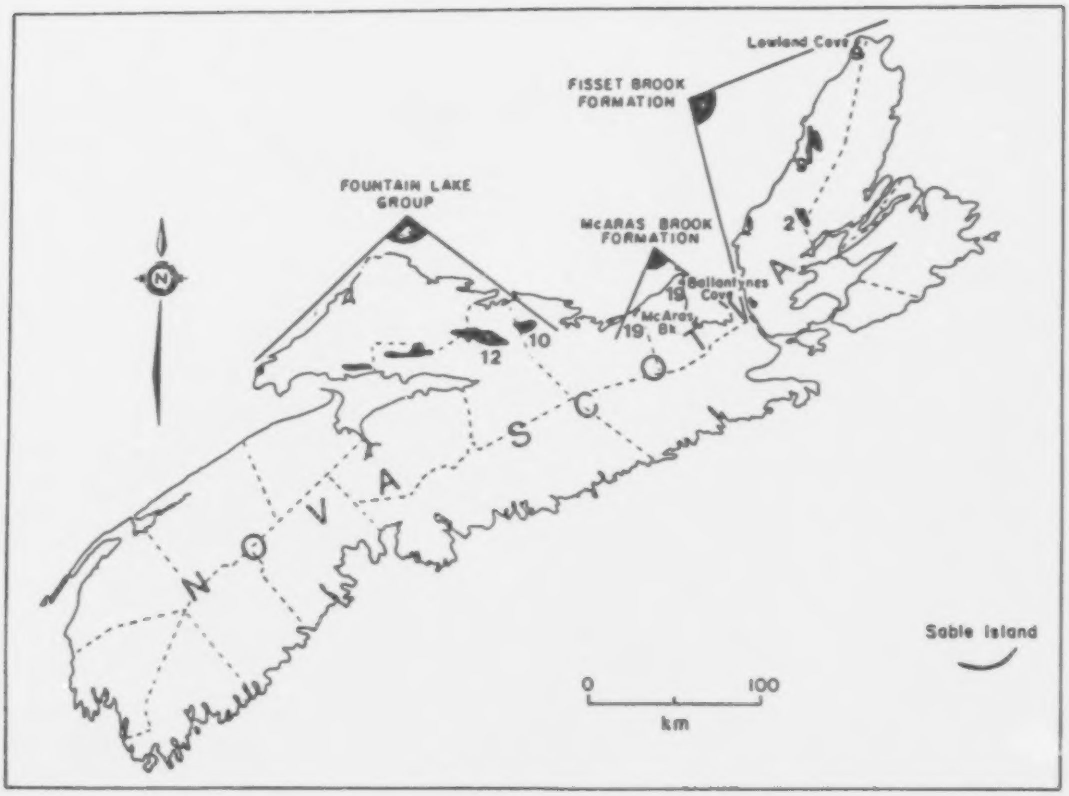

Lowland Cove
FISSET BROOK FORMATION
FOUNTAIN LAKE GROUP
McARAS BROOK FORMATION
Ballantynes Cove
McAras Bk
19
19
12
10
2
8
N
NOVA SCOTIA
Sable Island
0
100
km

FIGURE 27. Map showing the distribution of Devono-Carboniferous volcanic rocks in Nova Scotia and indicating numbers of the samples from each locality (after Dostal _et_ _al_. 1983).

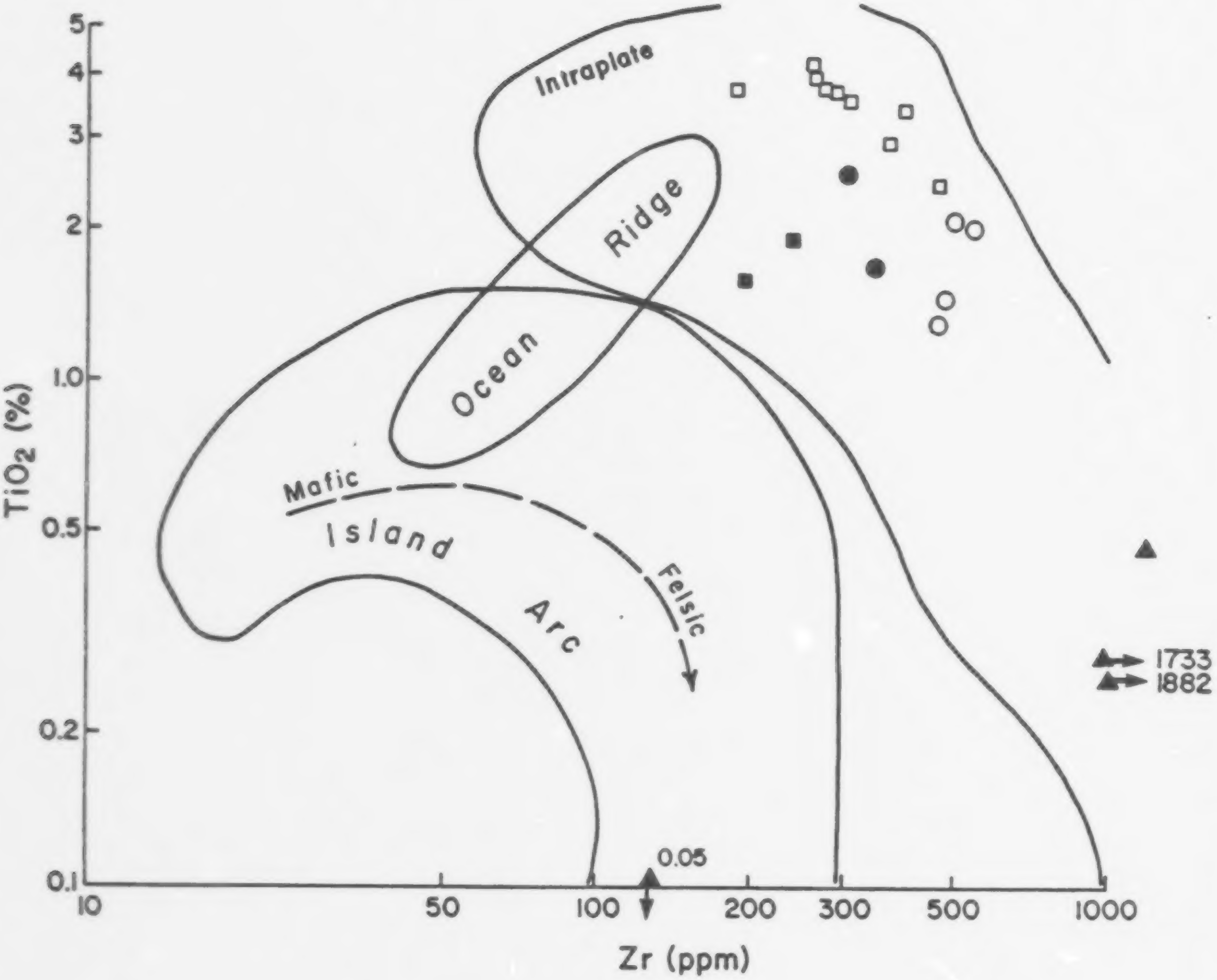


FIGURE 28. Discrimination diagram for volcanic rocks using TiO_2 versus Zr (after Gass 1982). Closed squares = Late Tournaisian to Early Viséan basalts; closed circles = Late Tournaisian to Early Viséan andesites; open squares = Late Viséan to Namurian basalts; open circles = Late Viséan to Namurian trachyandesites; triangles = felsic volcanic rocks (after Fyffe and Barr, in press).

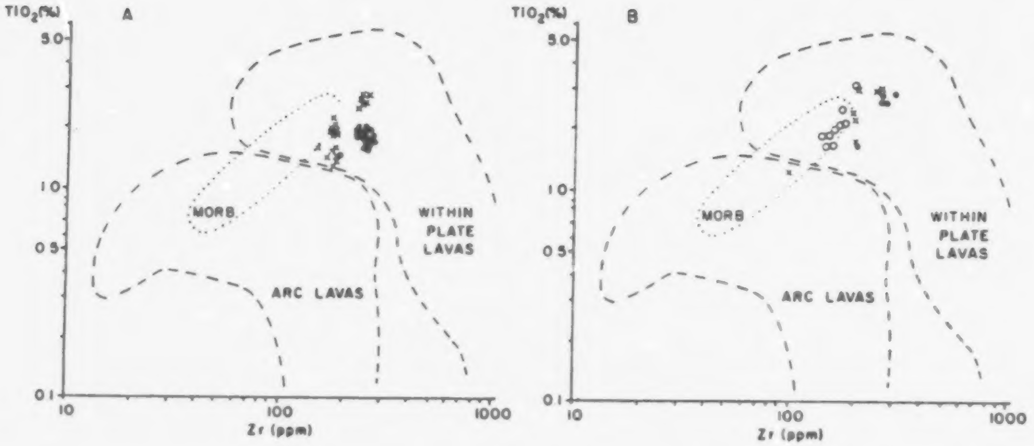


FIGURE 29. A - TiO_2-Zr diagram of Pearce et al. (1981) for the basalts of the McAras Brook Formation (o = Ballantynes Cove; x = type section). B - TiO_2-Zr diagram of Pearce et al. (1981) for the basalts from the Fountain Lake Group (X) and the Fisset Brook Formation at Lowland Cove (●) and the type section and Lake Ainslie (o) (after Dostal et al. 1983).

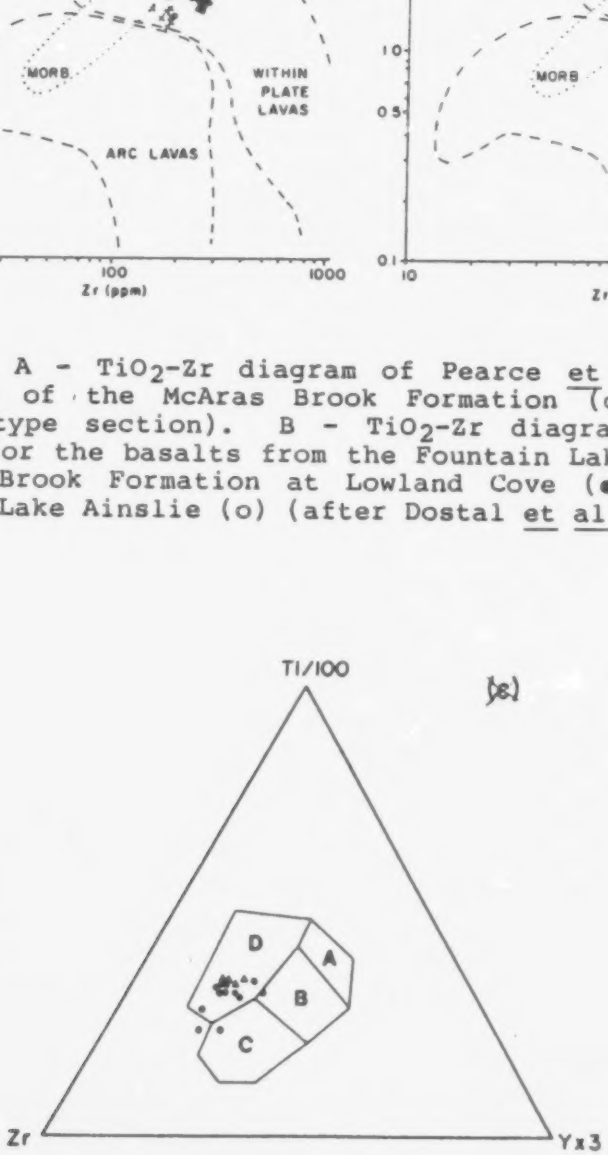


FIGURE 30. Discrimination plot for chemical affinity and tectonic setting, after Pearce and Cann (1973). Fields A and B are low potassium tholeiite; B is ocean-floor basalt; B and C are calc-alkalic basalt; D is within-plate basalt (after Barr et al. 1985).

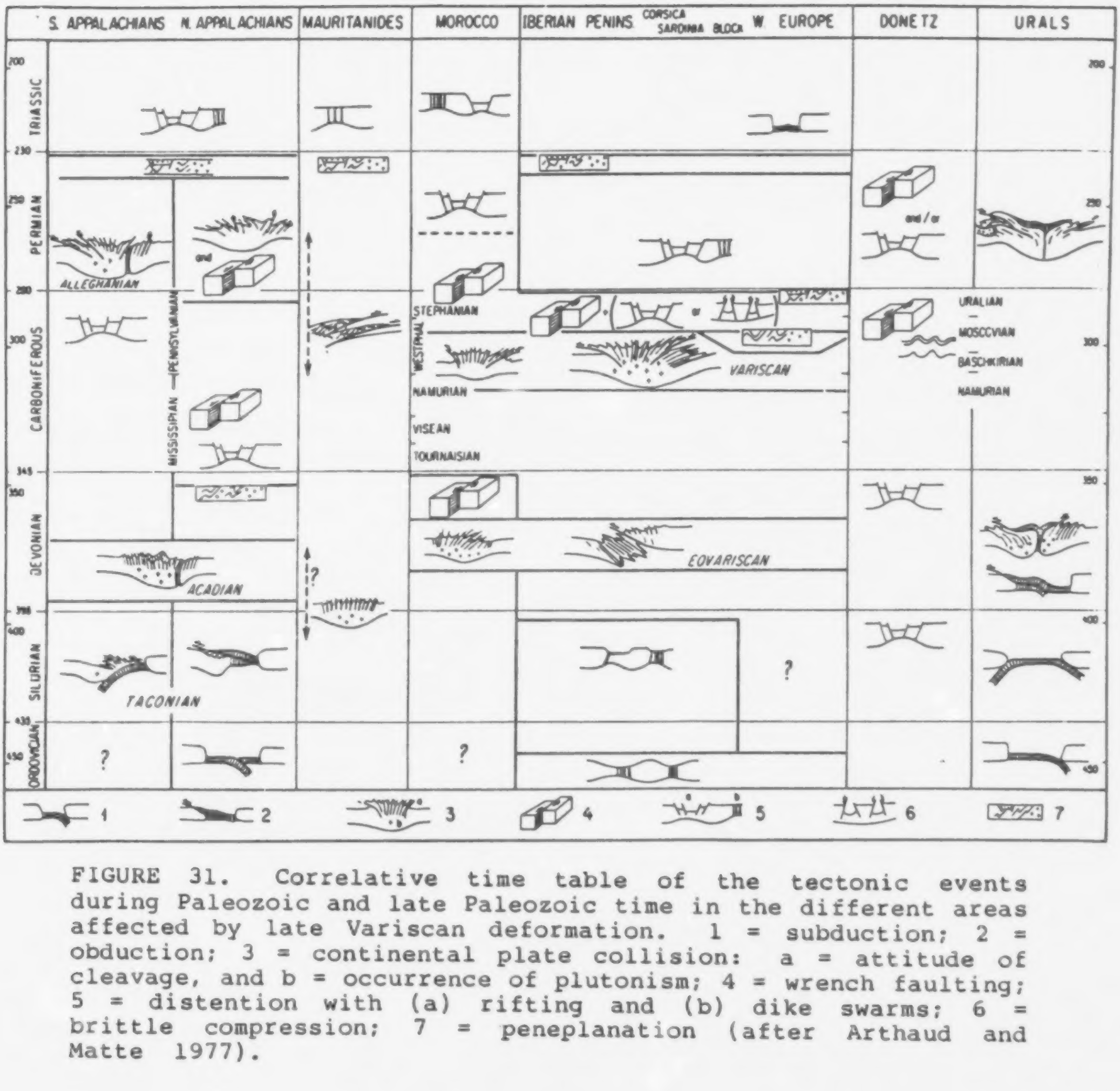

S. APPALACHIANS
N. APPALACHIANS
MAURITANIDES
MOROCCO
IBERIAN PENINS.
CORSICA SARDINIA BLOCK
W. EUROPE
DONETZ
URALS
TRIASSIC
PERMIAN
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
200
230
250
280
300
345
350
395
400
430
450
ALLEGHANIAN
MISSISSIPIAN
PENNSYLVANIAN
and
STEPHANIAN
WESTPHAL
NAMURIAN
VISEAN
TOURNAISIAN
or
VARISCAN
EOVARISCAN
ACADIAN
TACONIAN
and / or
URALIAN
MOSCOVIAN
BASCHKIRIAN
NAMURIAN
?
a
b
1
2
3
4
5
6
7

FIGURE 31. Correlative time table of the tectonic events during Paleozoic and late Paleozoic time in the different areas affected by late Variscan deformation. 1 = subduction; 2 = obduction; 3 = continental plate collision: a = attitude of cleavage, and b = occurrence of plutonism; 4 = wrench faulting; 5 = distention with (a) rifting and (b) dike swarms; 6 = brittle compression; 7 = peneplanation (after Arthaud and Matte 1977).

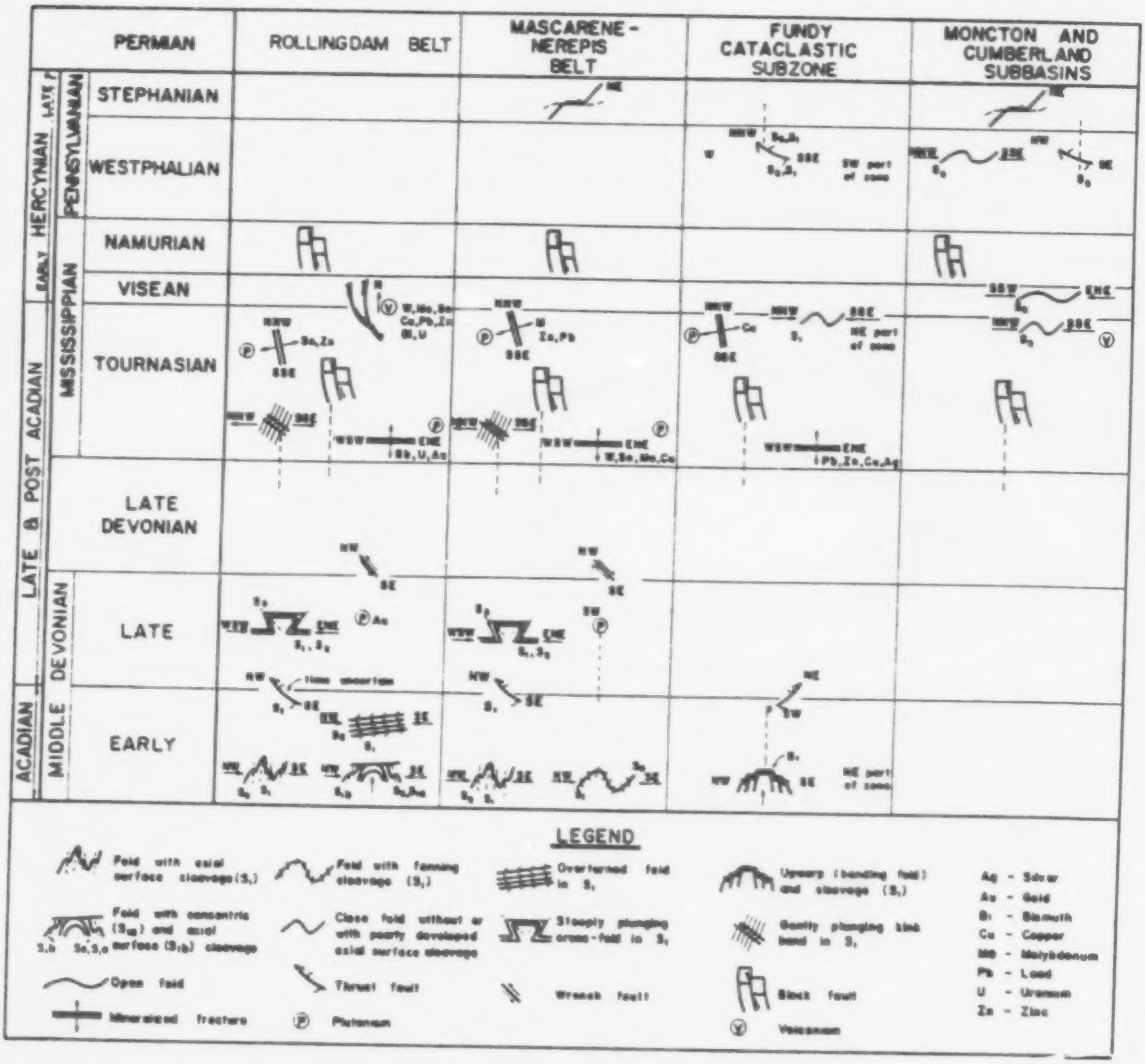

PERMIAN
ROLLINGDAM BELT
MASCARENE - NEREPIS BELT
FUNDY CATACLASTIC SUBZONE
MONCTON AND CUMBERLAND SUBBASINS
HERCYNIAN
LATE
EARLY
PENNSYLVANIAN
MISSISSIPPIAN
STEPHANIAN
WESTPHALIAN
NAMURIAN
VISEAN
TOURNASIAN
LATE & POST ACADIAN
LATE DEVONIAN
ACADIAN
MIDDLE DEVONIAN
LATE
EARLY
NW
SE
NE
SW
NNW
SSE
WSW
ENE
W,Mo,Sn
Cu,Pb,Zn
Bi,U
Sn,Zn
Zn,Pb
Cu
Sb,U,Au
W,Sn,Mo,Cu
Pb,Zn,Cu,Ag
Au
time uncertain
SW part of zone
NE part of zone
LEGEND
Fold with axial surface cleavage (S_1)
Fold with fanning cleavage (S_1)
Overturned fold in S_1
Upwarp (bending fold) and cleavage (S_1)
Fold with concentric (S_{1a}) and axial surface (S_{1b}) cleavage
Close fold without or with poorly developed axial surface cleavage
Steeply plunging cross-fold in S_1
Gently plunging kink band in S_1
Open fold
Thrust fault
Wrench fault
Block fault
Mineralized fracture
Plutonism
Volcanism
Ag - Silver
Au - Gold
Bi - Bismuth
Cu - Copper
Mo - Molybdenum
Pb - Lead
U - Uranium
Zn - Zinc

FIGURE 32. Table showing deformation episodes in southern New Brunswick (after Ruitenberg and McCutcheon 1982).

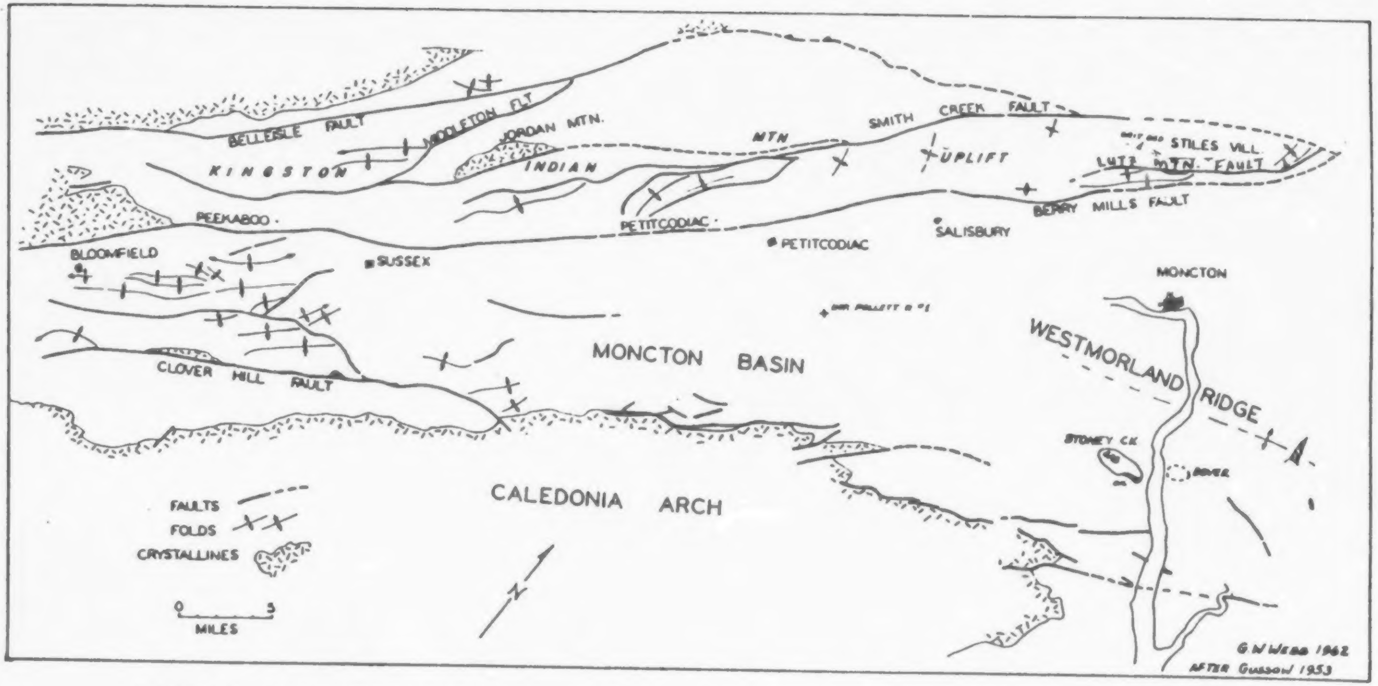

BELLEISLE FAULT
MIDDLETON FLT
JORDAN MTN.
KINGSTON
INDIAN
MTN
SMITH CREEK FAULT
UPLIFT
STILES VILL.
LUTZ MTN. FAULT
BERRY MILLS FAULT
PEEKABOO
PETITCODIAC
PETITCODIAC
SALISBURY
BLOOMFIELD
SUSSEX
MONCTON
MONCTON BASIN
WESTMORLAND RIDGE
A
CLOVER HILL FAULT
STONEY CK.
DOVER
CALEDONIA ARCH
FAULTS
FOLDS
CRYSTALLINES
0
3
MILES
N
G.N.WEBB 1962
AFTER GUSSOW 1953

FIGURE 33. Tectonic map of Moncton Basin and adjacent areas showing folds in Moncton and older stata. These folds could have been formed synchronously with those in Figure 35, in latest Mississippian Hopewell episode, but their predominant obliqueness to major faults suggests otherwise. They should have been formed when principal compression was approximately east-west and major faults were functioning as right-lateral strike-slip shears, perhaps during pre-Windsor Moncton episode. Regional stress field appears to have been rotated in clockwise direction from that time into Pennsylvanian (after Webb 1963).

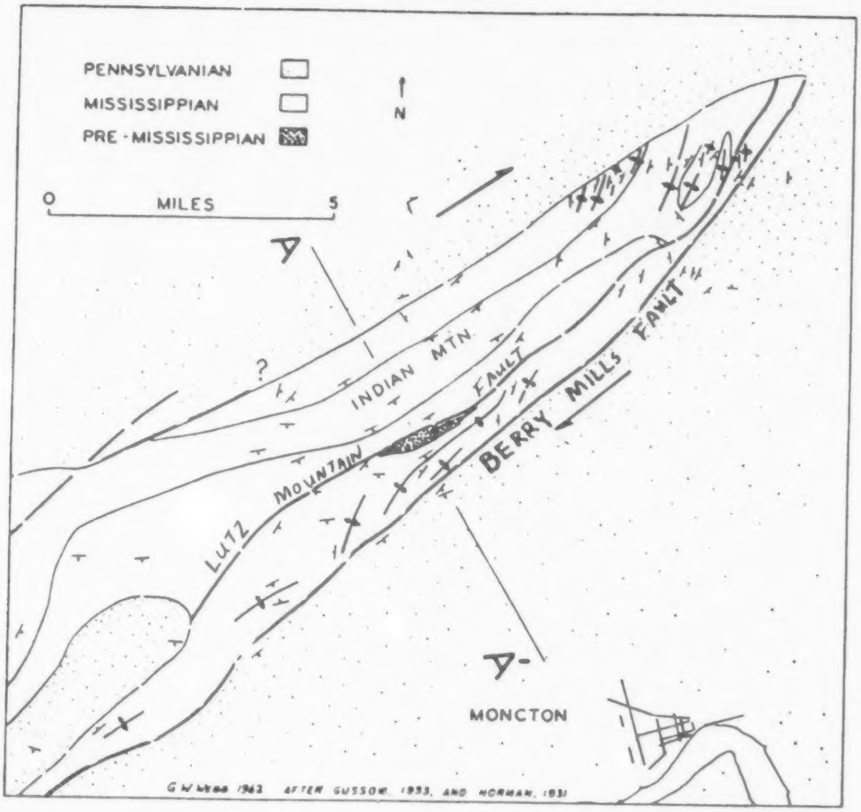

PENNSYLVANIAN
MISSISSIPPIAN
PRE-MISSISSIPPIAN
N
0
MILES
5
?
INDIAN MTN.
FAULT
LUTZ MOUNTAIN
BERRY MILLS FAULT
MONCTON
G W WEBB 1962 AFTER GUSSOW, 1953, AND NORMAN, 1931

FIGURE 34. Tectonic map of Indian Mountain area, north of Moncton. Dip-strikes and fold axes in highly deformed Mississippian rocks indicate by their oblique orientations to major faults that right-lateral slip was important (after Webb 1963).

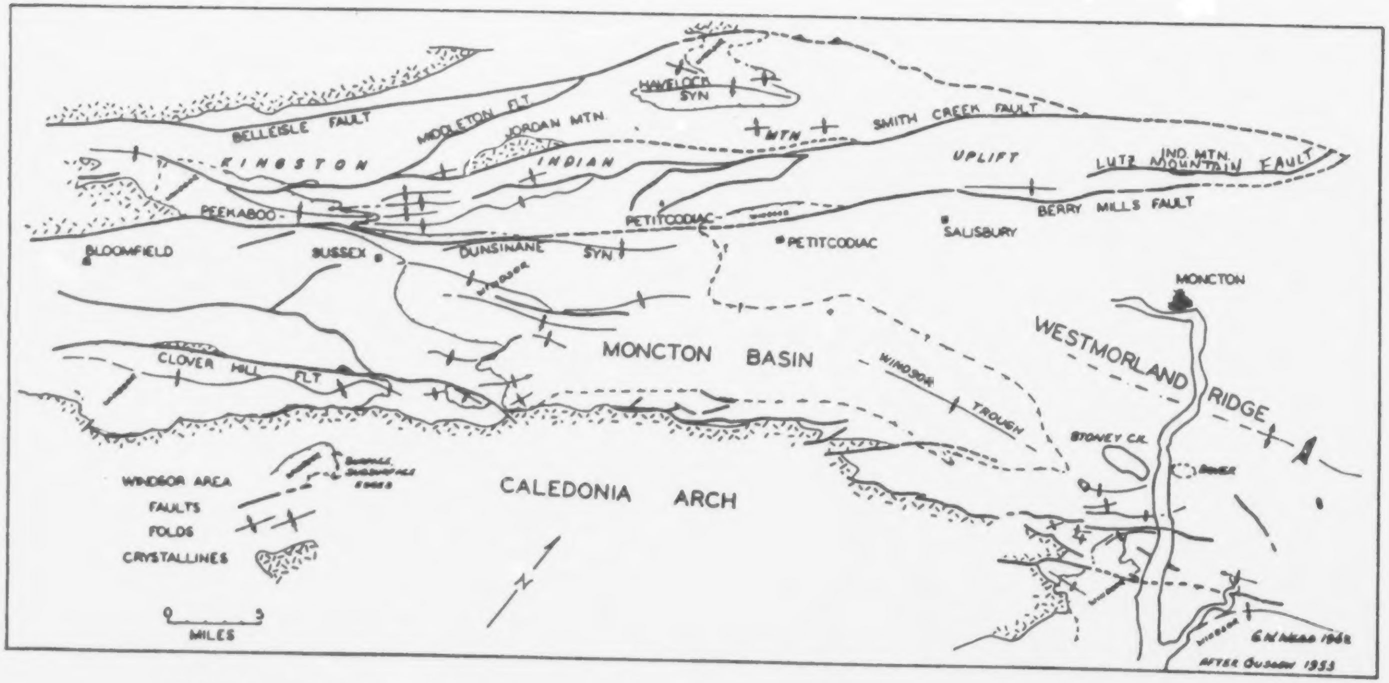

BELLEISLE FAULT
MIDDLETON FLT
JORDAN MTN.
HAVELOCK SYN
MTN
SMITH CREEK FAULT
KINGSTON
INDIAN
UPLIFT
LUTZ MOUNTAIN FAULT
IND. MTN.
PEEKABOO
PETITCODIAC
BERRY MILLS FAULT
BLOOMFIELD
SUSSEX
DUNSINANE SYN
WINDSOR
PETITCODIAC
SALISBURY
MONCTON
MONCTON BASIN
WINDSOR TROUGH
WESTMORLAND RIDGE
CLOVER HILL FLT
STONEY CR.
CALEDONIA ARCH
WINDSOR AREA
FAULTS
FOLDS
CRYSTALLINES
N
0
3
MILES
WINDSOR
G.W. WEBB 1962
AFTER GUSSOW 1953

FIGURE 35. Tectonic map of Moncton Basin and adjacent areas showing folds which affect post-Moncton strata (Windsor and younger), and so must be of latest Mississippian Hopewell age or, to some extent, of Pennsylvanian age. Parallelism of major faults and of fold axes implies that principal compression was across their strikes and that thrust faulting probably dominated at the time. Scattered Windsor occurrences are shown, possibly but not necessarily offset by strike-slips (after Webb 1963).

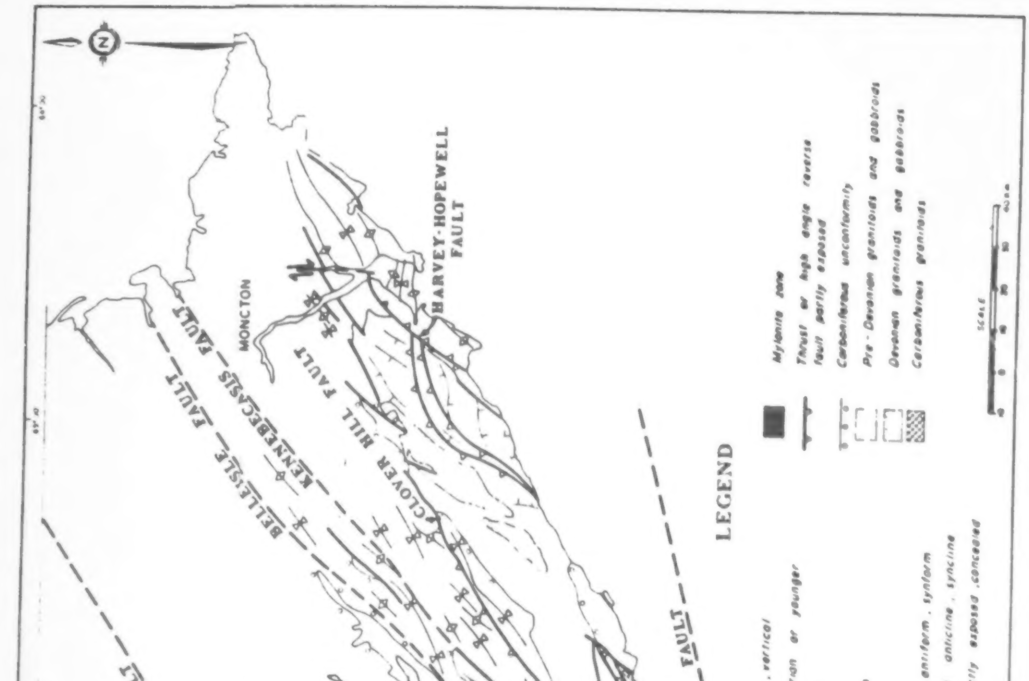

FREDERICTON FAULT
BELLEISLE FAULT
KENNEBECASIS FAULT
CLOVER HILL FAULT
HARVEY-HOPEWELL FAULT
COBEQUID FAULT
MAGAGUADAVIC FAULT
OAK BAY FAULT
ST. GEORGE-SAINT JOHN FAULT
MONCTON
FREDERICTON
SAINT JOHN
CAMPOBELLO ISLAND
GRAND MANAN ISLAND
LEGEND
Cleavage inclined, vertical
Precambrian or younger
Taconian
Acadian
Hercynian
Fold axes
Acadian antiform, synform
Hercynian anticline, syncline
Fault partly exposed, concealed
Mylonite zone
Thrust or high angle reverse fault partly exposed
Carboniferous unconformity
Pre-Devonian granitoids and gabbroids
Devonian granitoids and gabbroids
Carboniferous granitoids
SCALE

FIGURE 36. Structural geology map of southern New Brunswick (after Ruitenberg and McCutcheon 1982).

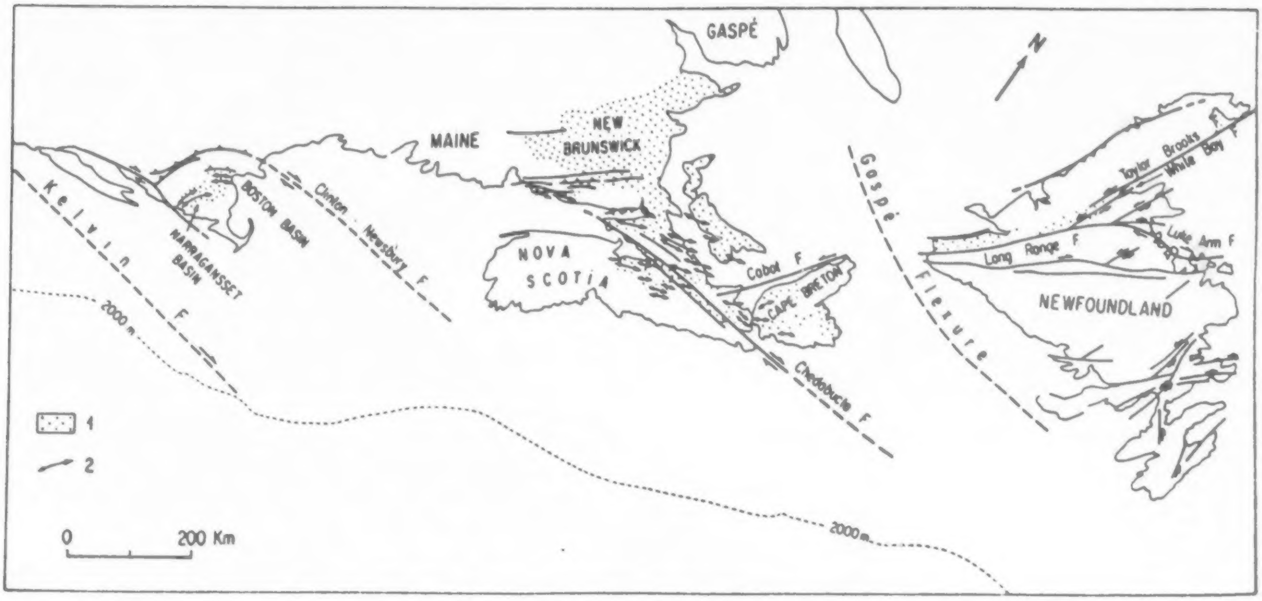
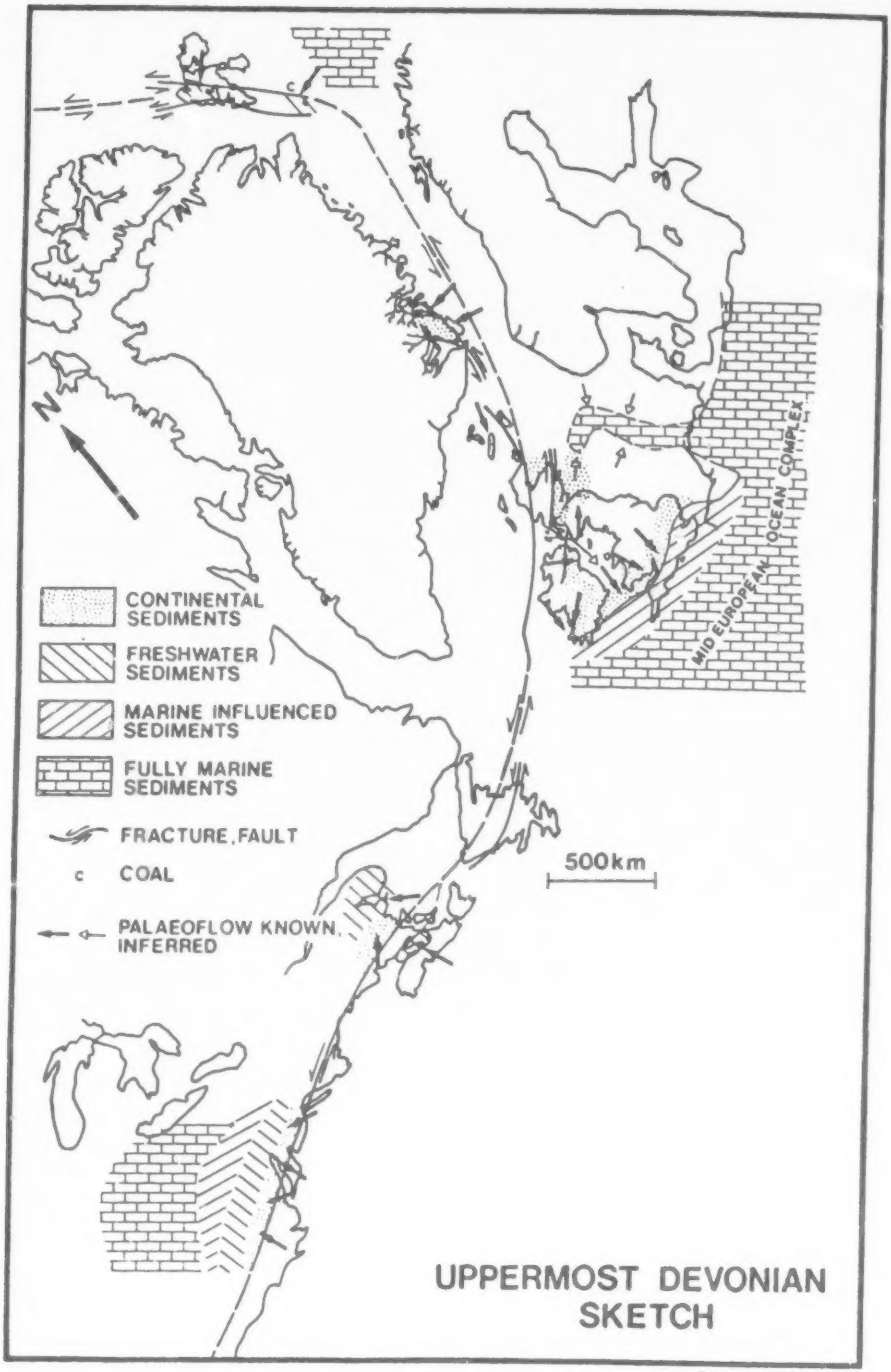
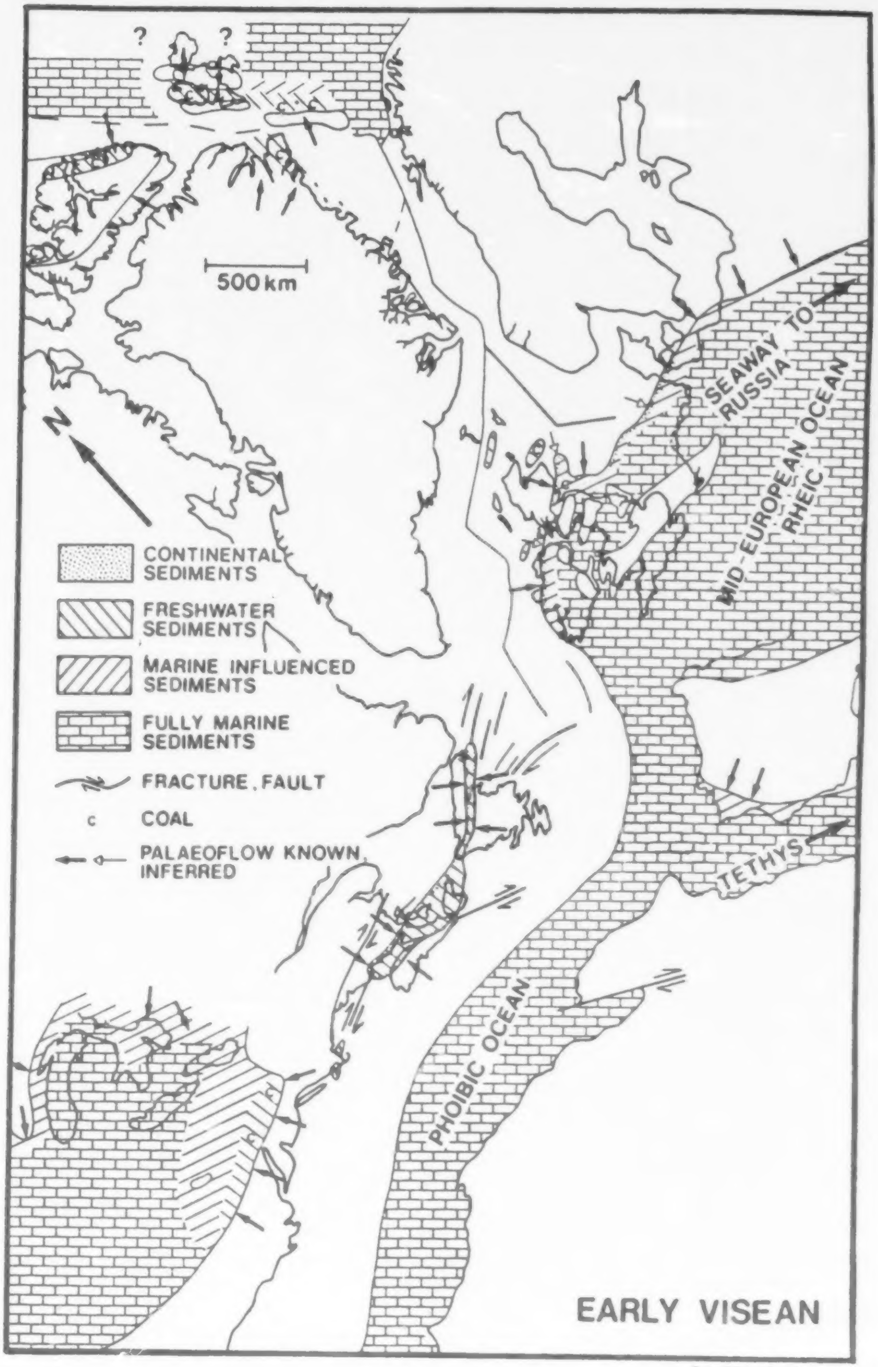

GASPÉ
N
MAINE
NEW BRUNSWICK
Kelvin F
NARRAGANSSET BASIN
BOSTON BASIN
Clinton Newsbury F
NOVA SCOTIA
Cabot F
CAPE BRETON
Chedabucto F
Gaspé Flexure
Taylor Brooks F
White Bay F
Long Range F
Luke Arm F
NEWFOUNDLAND
2000 m
2000 m
1
2
0
200 Km

FIGURE 37. Late Variscan structures in northern and maritime Appalachians. This area is the junction between the late Variscan shear zone and the southern Appalachians folded belt. Folds and thrusts transform the offset of wrench faults (mainly right-lateral). 1 = Carboniferous deposits; 2 = folds (after Arthaud and Matte 1977).


CONTINENTAL SEDIMENTS
FRESHWATER SEDIMENTS
MARINE INFLUENCED SEDIMENTS
FULLY MARINE SEDIMENTS
FRACTURE, FAULT
c COAL
PALAEOFLOW KNOWN, INFERRED
c
500 km
N
MID EUROPEAN OCEAN COMPLEX
UPPERMOST DEVONIAN SKETCH

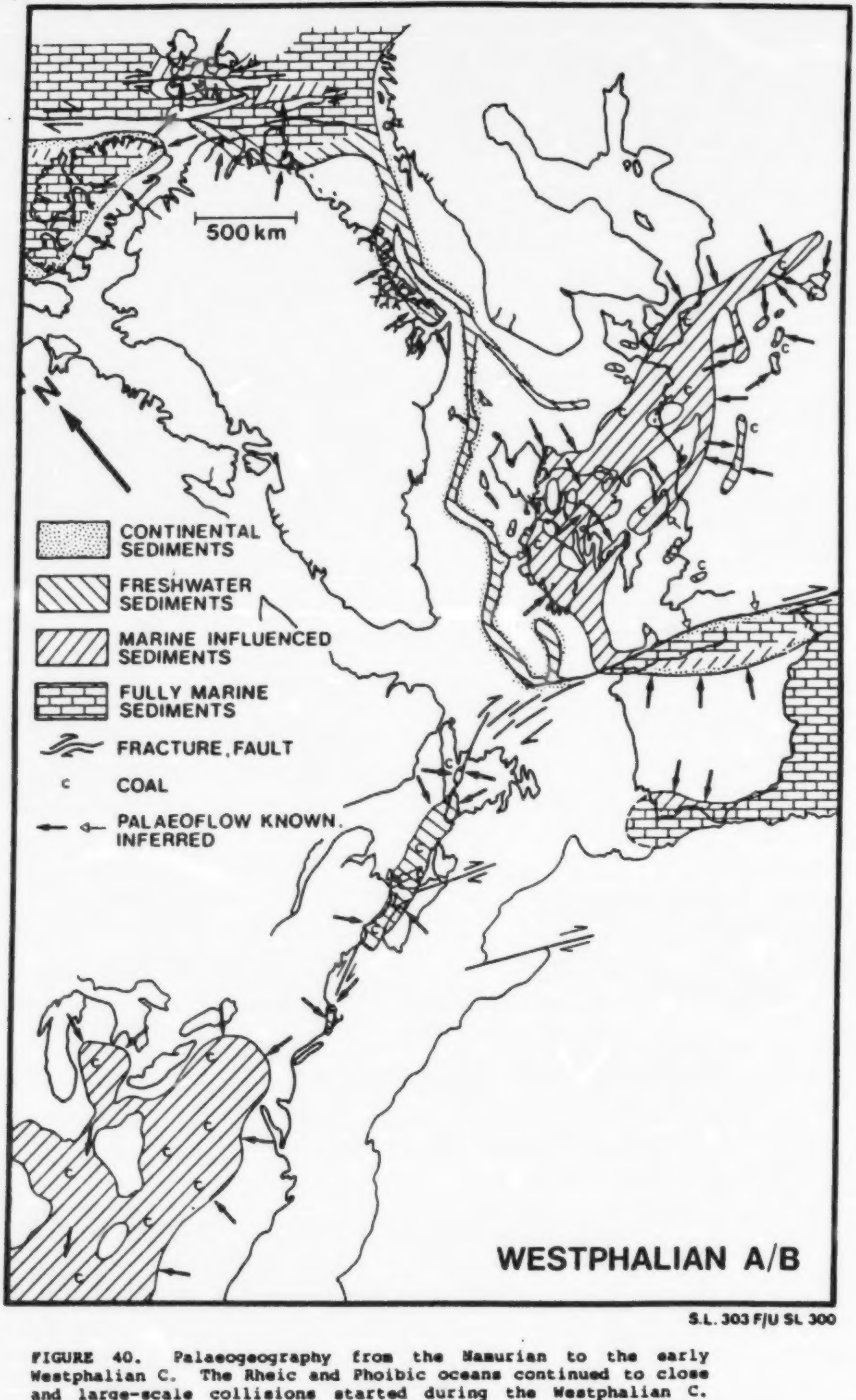
S.L. 302 F/U S.L. 300

FIGURE 38. Late Upper Devonian sketch map; any lateral displacements of landmasses not shown. Base map is part of a refit (oblique Mercator projection) by D.K. Smythe (unpublished). Details of Africa and mid-European Ocean omitted. Sinistral transcurrent faulting was dominant, shown palaeomagnetically in America and sedimentologically in central Scotland and Svalbard. The British Isles coastal plain may have been related to tension from mid-European Ocean subduction (Leeder 1982). Transgression into the North Sea may have been induced by mid-Devonian tension following closure of the Iapetus Ocean (after Haszeldine 1984).


?
?
500 km
N
CONTINENTAL SEDIMENTS
FRESHWATER SEDIMENTS
MARINE INFLUENCED SEDIMENTS
FULLY MARINE SEDIMENTS
FRACTURE, FAULT
c COAL
PALAEOFLOW KNOWN, INFERRED
SEAWAY TO RUSSIA
MID-EUROPEAN OCEAN
RHEIC
TETHYS
PHOIBIC OCEAN
EARLY VISEAN

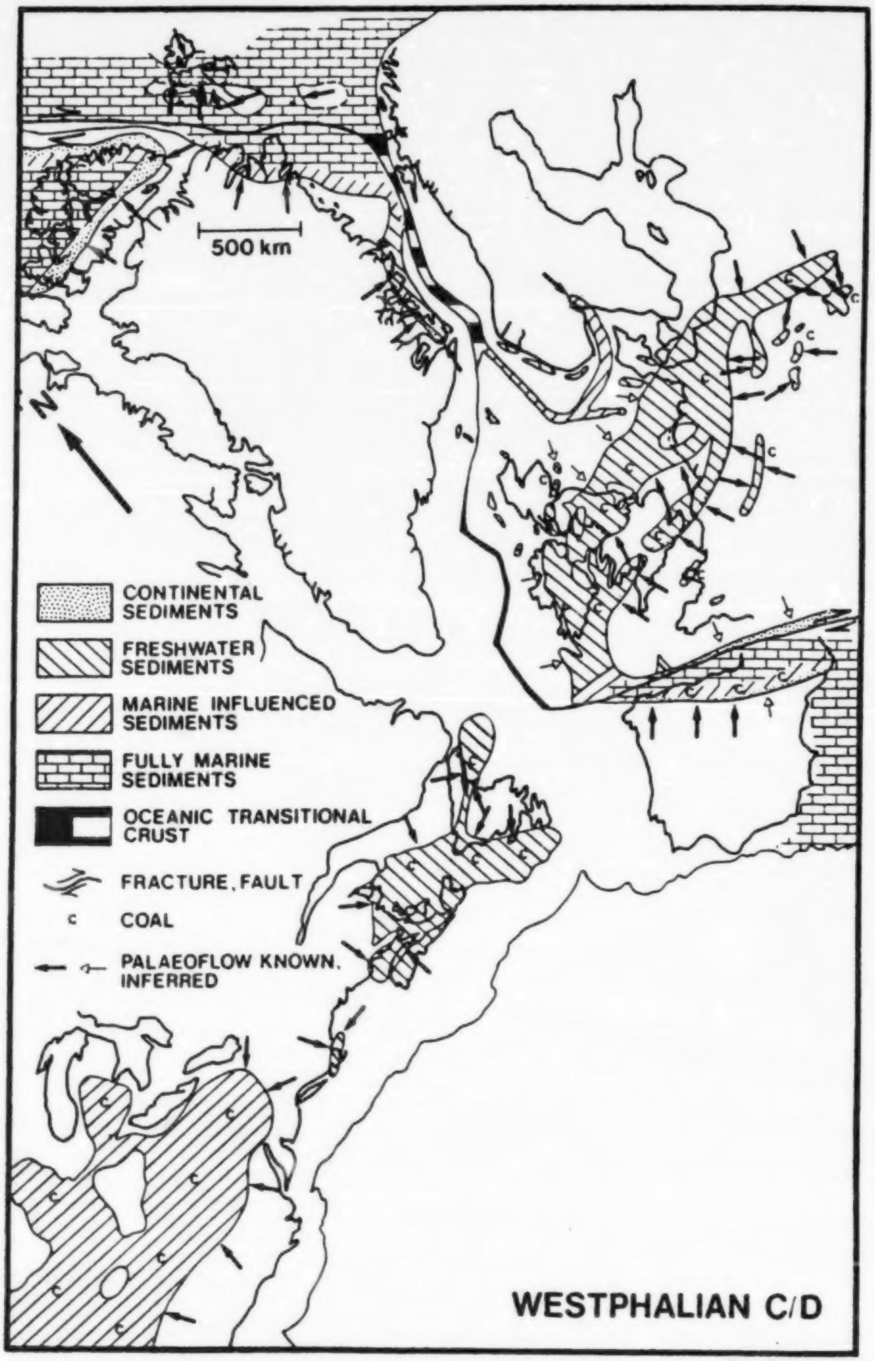
S.L. 301 F/U S.L. 300

FIGURE 39. Palaeogeography from the early Carboniferous to the latest Viséan. Positions of Africa and Spain are approximate, details of Rheic and Phoibic oceans are omitted. Dextral transcurrent faulting in Maritime America was probably related to ocean closure, and was dispersed across the British Isles. Faults drawn from Belt (1969) and Bradley (1982). The northeast-trending Taylors Brook Fault of Newfoundland was inactive after the early Viséan, so that dextral motion probably became progressively transferred towards Spain. The Viséan Windsor Group marine transgression in Newfoundland came from the U.S.A. (Jansa, Mamet and Roux 1978). The Tethyan Rheic sea transgressed the British Isles; synsedimentary ore deposits formed along north-south geofractures as a result of east-west tension. Dinantian volcanism and basin formation show crustal tension and thinning; buoyant granite-cored blocks floated as "highs" (after Haszeldine 1984).


500 km
N
CONTINENTAL SEDIMENTS
FRESHWATER SEDIMENTS
MARINE INFLUENCED SEDIMENTS
FULLY MARINE SEDIMENTS
FRACTURE, FAULT
c COAL
PALAEOFLOW KNOWN, INFERRED
c
WESTPHALIAN A/B

S.L. 303 F/U SL 300

FIGURE 40. Palaeogeography from the Namurian to the early Westphalian C. The Rheic and Phoibic oceans continued to close and large-scale collisions started during the Westphalian C. Clastic sources for the British Isles and the U.S.A. were rejuvenated in the Namurian A; transcurrent stress and faulting started in North Spain and Svalbard at this time, as did subsidence of the East Greenland basins. A Namurian A episode of crustal fracturing is inferred, due to collision of part of the Phoibic Ocean with America. Namurian or Westphalian sediments have been drilled in the northern Porcupine Seabight, the southeast margin of the Rockall Trough, the southeast Faeroe Basin and the Dogger High in the Central Graben (after Haszeldine 1984).


500 km
N
CONTINENTAL SEDIMENTS
FRESHWATER SEDIMENTS
MARINE INFLUENCED SEDIMENTS
FULLY MARINE SEDIMENTS
OCEANIC TRANSITIONAL CRUST
FRACTURE, FAULT
c COAL
PALAEOFLOW KNOWN, INFERRED
c
WESTPHALIAN C/D

S.L. 305 F/U 305

FIGURE 41. Palaeogeography from the mid-Westphalian C to lower Stephanian. Dextral faulting ceased in Maritime America, north-south basins ceased to subside in the British Isles, thick basins were east-west. A marine transgression entered the Oslo Graben, inferred to be Boreal, as no Tethyan marine faunas were present in northwest Europe at this time. Dextral faulting continued in Spain and Svalbard. Collision of Africa and America resulted in crustal rupture and formation of a nominal width of ocean crust. Crust failed to rupture south-east of the Faeroes and stress focused through this area resulting in thinning of the Faeroe Basin margins (after Haszeldine 1984).

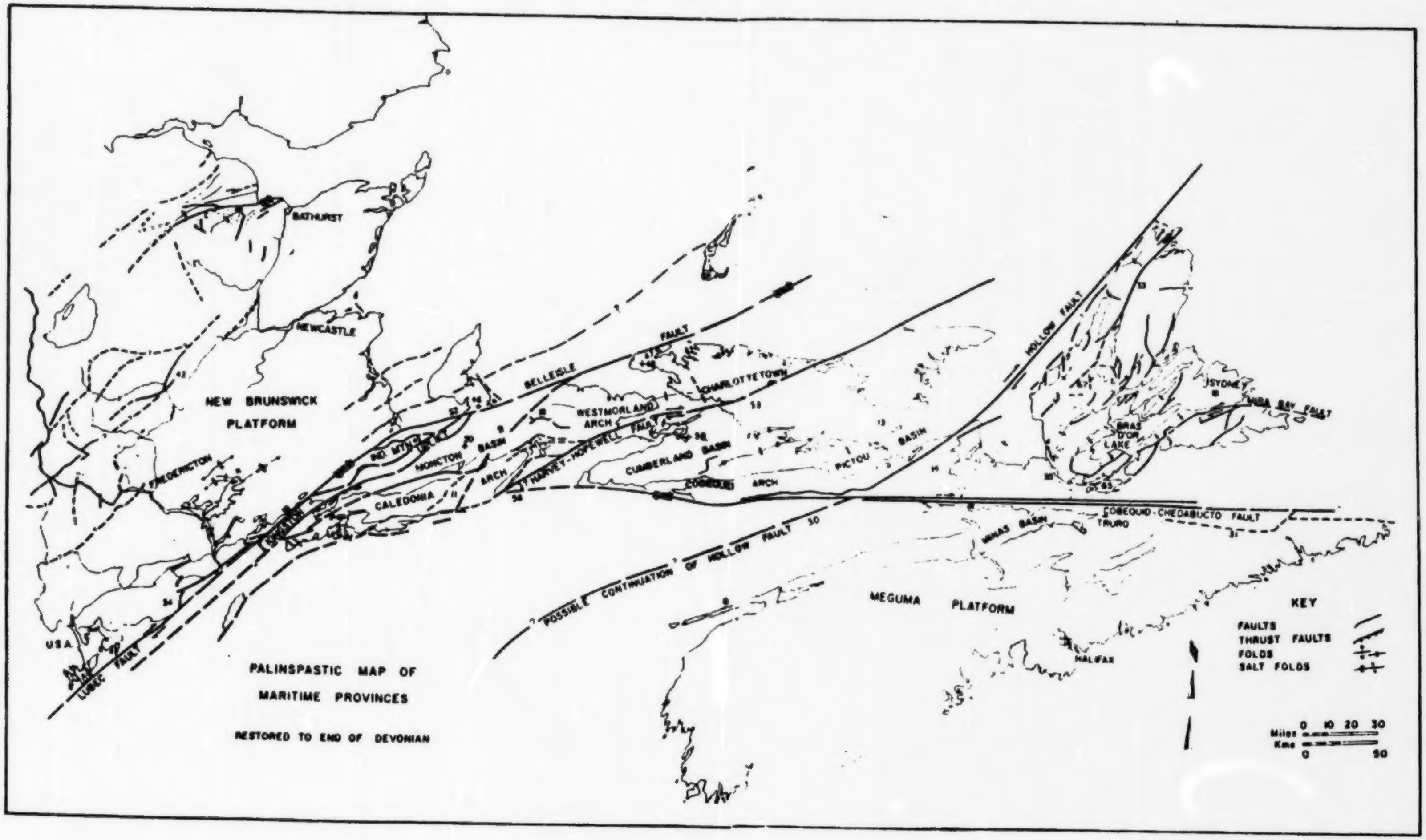

BATHURST
NEWCASTLE
NEW BRUNSWICK PLATFORM
FREDERICTON
USA
LUBEC FAULT
BELLEISLE FAULT
WESTMORLAND ARCH
HARVEY-HOPEWELL FAULT
MONCTON BASIN
CALEDONIA
ARCH
CUMBERLAND BASIN
COBEQUID ARCH
CHARLOTTETOWN
PICTOU BASIN
HOLLOW FAULT
POSSIBLE CONTINUATION OF HOLLOW FAULT
BRAS D'OR LAKE
SYDNEY
MIRA BAY FAULT
COBEQUID-CHEDABUCTO FAULT
MINAS BASIN
TRURO
MEGUMA PLATFORM
HALIFAX
PALINSPASTIC MAP OF
MARITIME PROVINCES
RESTORED TO END OF DEVONIAN
KEY
FAULTS
THRUST FAULTS
FOLDS
SALT FOLDS
Miles 0 10 20 30
Kms 0 50

FIGURE 42. Palinspastic map of Maritime Provinces with deformation restored to approximately latest Devonian (after Webb 1969).

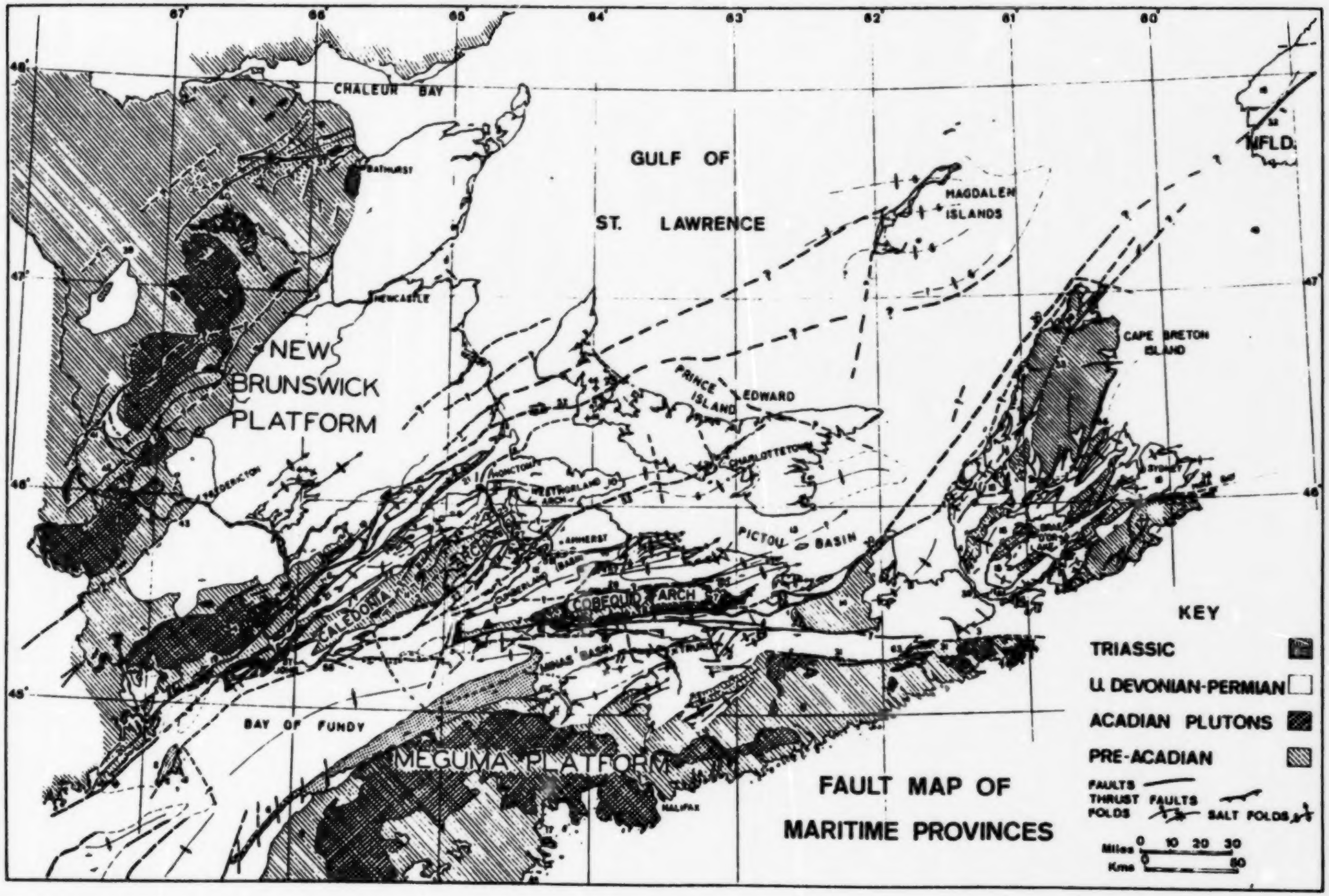

CHALEUR BAY
BATHURST
NEWCASTLE
NEW BRUNSWICK PLATFORM
FREDERICTON
GULF OF ST. LAWRENCE
MAGDALEN ISLANDS
NFLD.
CAPE BRETON ISLAND
PRINCE EDWARD ISLAND
CHARLOTTETOWN
MONCTON
WESTMORLAND ARCH
AMHERST
PICTOU BASIN
SYDNEY
CALEDONIA
COBEQUID ARCH
MINAS BASIN
BAY OF FUNDY
MEGUMA PLATFORM
HALIFAX
FAULT MAP OF MARITIME PROVINCES
KEY
TRIASSIC
U. DEVONIAN-PERMIAN
ACADIAN PLUTONS
PRE-ACADIAN
FAULTS
THRUST FAULTS
FOLDS
SALT FOLDS
Miles 0 10 20 30
Kms 0 50
67°
66°
65°
64°
63°
62°
61°
60°
48°
47°
46°
45°

FIGURE 43. Fault map of Maritime Provinces. Upper Devonian-Permian and Triassic cover rocks are differentiated from Acadian and pre-Acadian basement complex. Small index numbers refer to localities and features cited in text (after Webb 1969).

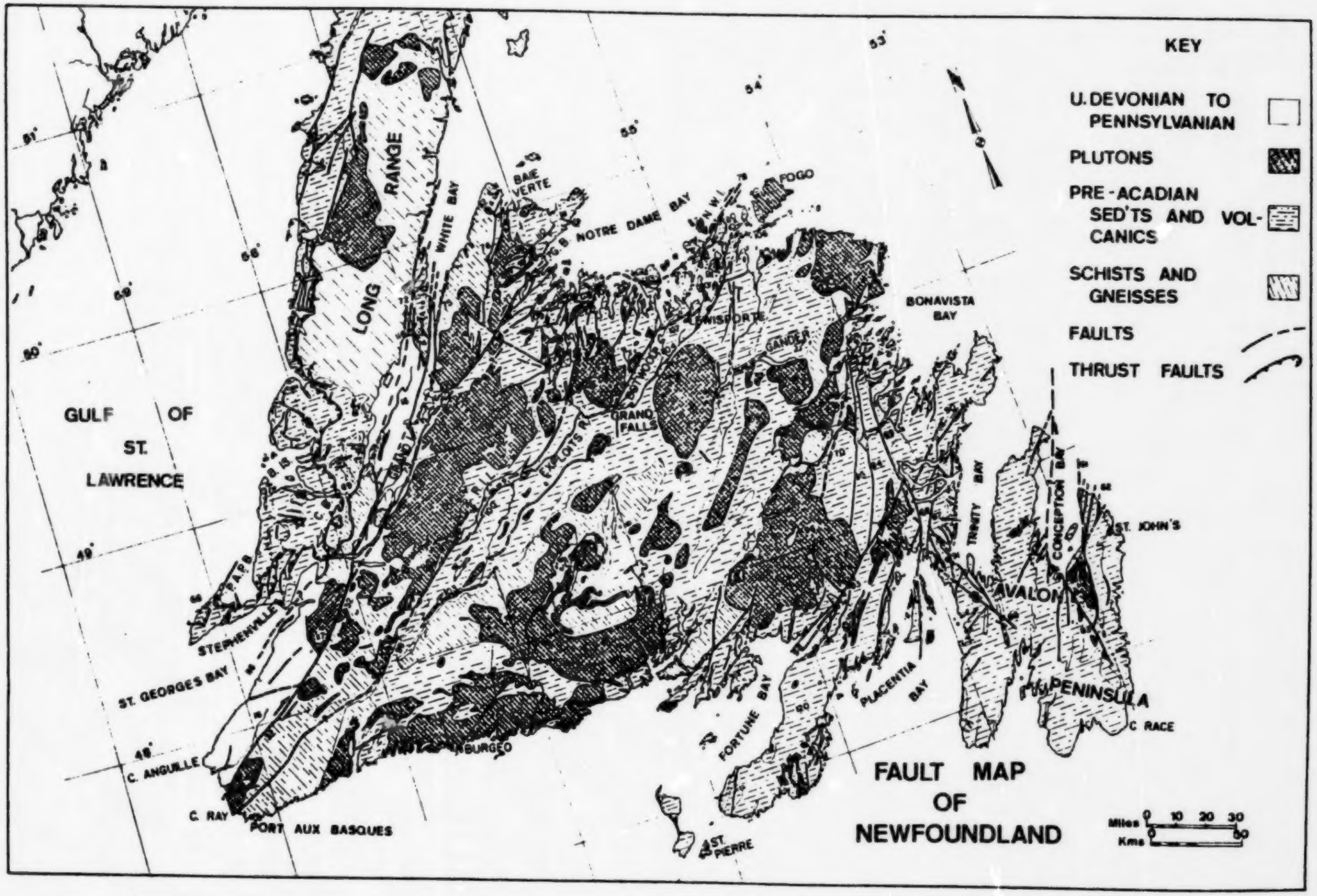

KEY
U.DEVONIAN TO PENNSYLVANIAN
PLUTONS
PRE-ACADIAN SED'TS AND VOL-CANICS
SCHISTS AND GNEISSES
FAULTS
THRUST FAULTS
GULF OF ST. LAWRENCE
LONG RANGE
WHITE BAY
BAIE VERTE
NOTRE DAME BAY
FOGO
BONAVISTA BAY
LEWISPORTE
GANDER
GRAND FALLS
TRINITY BAY
CONCEPTION BAY
ST. JOHN'S
AVALON
PENINSULA
C RACE
PLACENTIA BAY
FORTUNE BAY
ST. PIERRE
BURGEO
PORT AUX BASQUES
C. RAY
C. ANGUILLE
ST. GEORGES BAY
STEPHENVILLE
FAULT MAP OF NEWFOUNDLAND
Miles 0 10 20 30
Kms 0 50
53°
54°
55°
56°
59°
60°
61°
49°
48°

FIGURE 44. Fault map of Newfoundland. Upper Devonian Pennsylvanian cover strata are differentiated from plutons, high-grade metamorphic rocks, and pre-Acadian sedimentary and volcanic rocks. The notation for Birchy Lake fault (108) now shown in Notre Dame Bay at approximately 49°40'N, 55°45'W, should be shown beside main northeast-trending fault at approximately 49°20'N, 56°45'W (after Webb 1969).

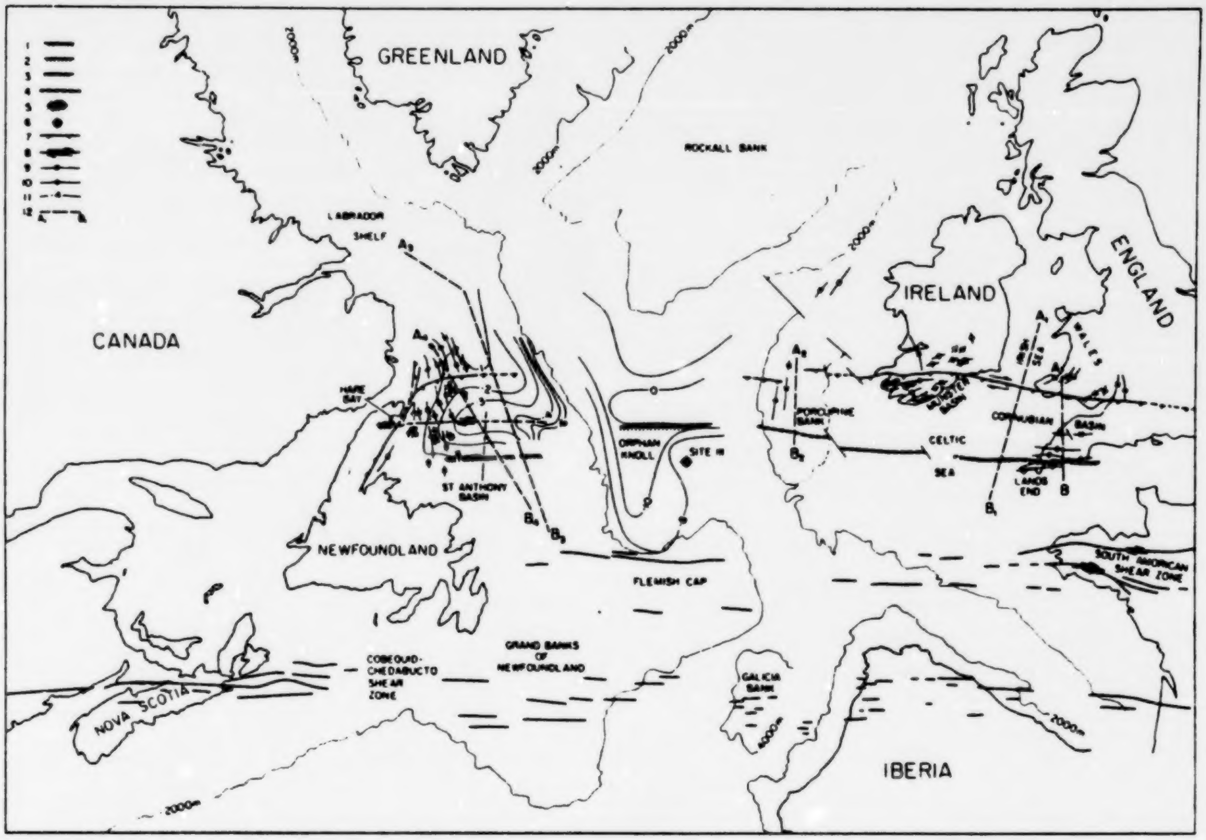

1
2
3
4
5
6
7
8
9
10
11
12
A
B
GREENLAND
2000m
ROCKALL BANK
LABRADOR SHELF
A₃
CANADA
A₄
HARE BAY
2
3
0
ORPHAN KNOLL
SITE III
ST ANTHONY BASIN
B₄
B₃
NEWFOUNDLAND
FLEMISH CAP
COBEQUID-CHEDABUCTO SHEAR ZONE
GRAND BANKS OF NEWFOUNDLAND
NOVA SCOTIA
GALICIA BANK
IRELAND
ENGLAND
WALES
A₂
PORCUPINE BANK
B₂
CELTIC SEA
CORNUBIAN BASIN
A₁
A
LANDS END
B
B₁
SOUTH AMORICAN SHEAR ZONE
IBERIA

FIGURE 45. Transatlantic correlation between Variscan structures on the Canadian and European continental margins restored to their locations as inferred by Lefort (1980), but with Porcupine seabight closed as defined by Lefort and Max (1984). Patterns are keyed as follows: (1) southern edge of basement low from seismic reflection (Wade et al., 1975); (2) northern edge of basement high from gravity data (Shih, in Keen and Hyndman, 1979); (3) Lower Devonian, Middle Devonian and Namuro-Westphalian flexure and fault; (4) short-wavelength magnetic belt; (5) post-Silurian doming; (6) well locations; (7) Variscan front (thrust and shear); (8) shear zones (transcurrent); (9) Variscan age basins and synclines; (10) Variscan uplifts and anticlines; (11) depth to basement in kilometres on southern Labrador Shelf; or free air gravity anomalies adjacent to Orphan Knoll; (12) structural sections (after Lefort and Haworth 1984).

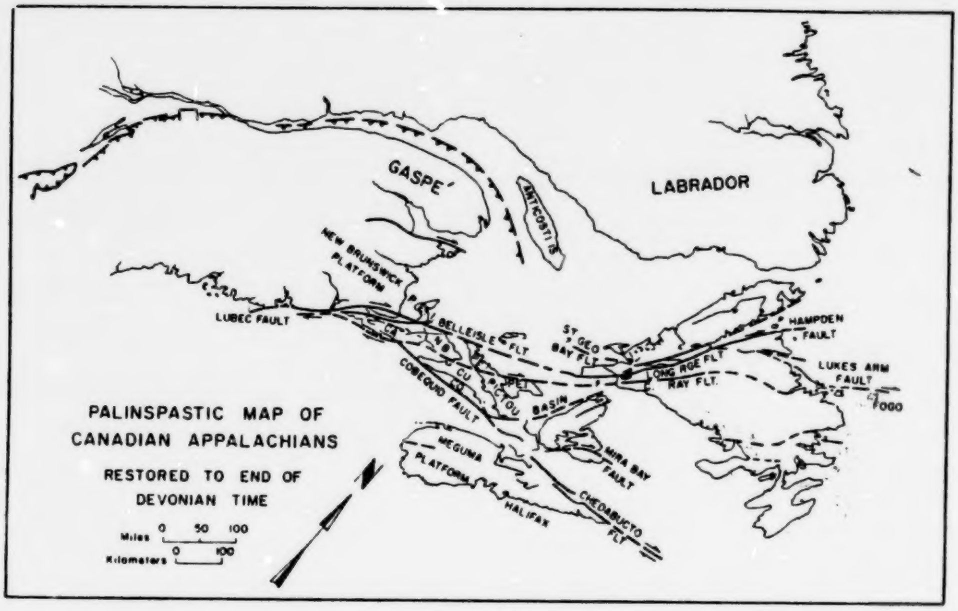

GASPE'
LABRADOR
ANTICOSTI IS
NEW BRUNSWICK PLATFORM
LUBEC FAULT
CA
NB
CU
CO
BELLEISLE FLT
COBEQUID FAULT
PICTOU BASIN
ST GEO BAY FLT
LONG RGE FLT
RAY FLT.
HAMPDEN FAULT
LUKES ARM FAULT
FOGO
MEGUMA PLATFORM
HALIFAX
MIRA BAY FAULT
CHEDABUCTO FLT
PALINSPASTIC MAP OF CANADIAN APPALACHIANS
RESTORED TO END OF DEVONIAN TIME
Miles 0 50 100
Kilometers 0 100

FIGURE 46. Palinspastic map of Canadian Appalachians with deformation restored to approximately latest Devonian. Maritime Provinces part is shown essentially as in Figure 42, but Newfoundland part is shown in two differing versions. Solid-outline version is based on restoration of only 100 km of dextral wrenching, on Long Range fault system. Dotted-outline version is based on restoration of approximately 160 km of dextral wrenching 100 km on Long Range fault system and remainder on Cape Ray-Victoria Lake-Dildo line. Anorthosite complexes are shown in black. CA = Caledonian; CO = Cobequid, Cu = Cumberland (after Webb 1969).

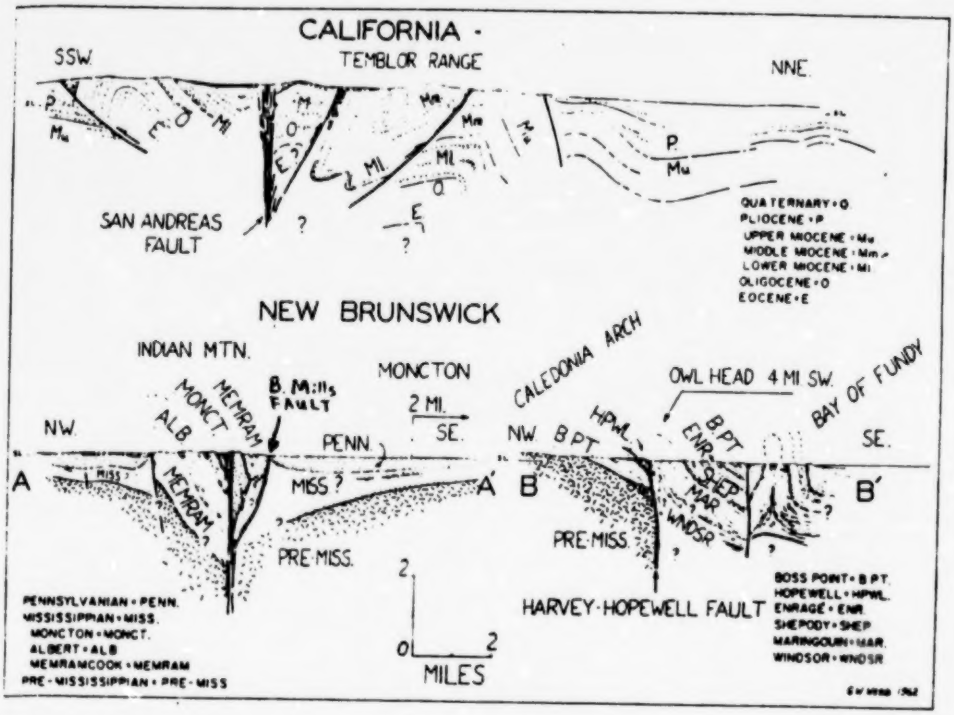

CALIFORNIA -
TEMBLOR RANGE
SSW.
NNE.
P
Mu
E
O
Ml
M
Mm
P
Mu
SAN ANDREAS FAULT
?
QUATERNARY • Q
PLIOCENE • P
UPPER MIOCENE • Mu
MIDDLE MIOCENE • Mm
LOWER MIOCENE • Ml
OLIGOCENE • O
EOCENE • E
NEW BRUNSWICK
INDIAN MTN.
MONCTON
NW.
ALB
MONCT.
MEMRAM
B. Mills FAULT
2 MI.
SE.
PENN.
MISS
MISS ?
MEMRAM
PRE-MISS.
A
A'
CALEDONIA ARCH
OWL HEAD 4 MI SW.
BAY OF FUNDY
NW.
B PT
HPWL
B PT
ENR
SHEP
MAR
WNDSR
SE.
B
B'
PRE-MISS.
HARVEY-HOPEWELL FAULT
PENNSYLVANIAN • PENN.
MISSISSIPPIAN • MISS.
MONCTON • MONCT.
ALBERT • ALB
MEMRAMCOOK • MEMRAM
PRE-MISSISSIPPIAN • PRE-MISS
BOSS POINT • B PT.
HOPEWELL • HPWL.
ENRAGE • ENR.
SHEPODY • SHEP
MARINGOUIN • MAR.
WINDSOR • WNDSR
2
0
2
MILES

FIGURE 47. Structure cross sections showing subsurface interpretations across major fault zones. California section is taken across San Andreas fault from Cuyama Valley into San Joaquin Valley, in Eocene and younger strata, based on considerable well control. Section A-A' (Figure 34) crosses Indian Mountain uplift and its included diorite basement sliver, with faults believed to be branches of major right-lateral strike-slip system; based mostly on surface control. Section B-B' from Caledonia arch across Harvey-Hopewell fault into Bay of Fundy shows close juxtaposition of contrasting Hopewell facies due to strike-slip offset, as well as décollement folds in basinal block; based entirely on surface control (after Webb 1963).

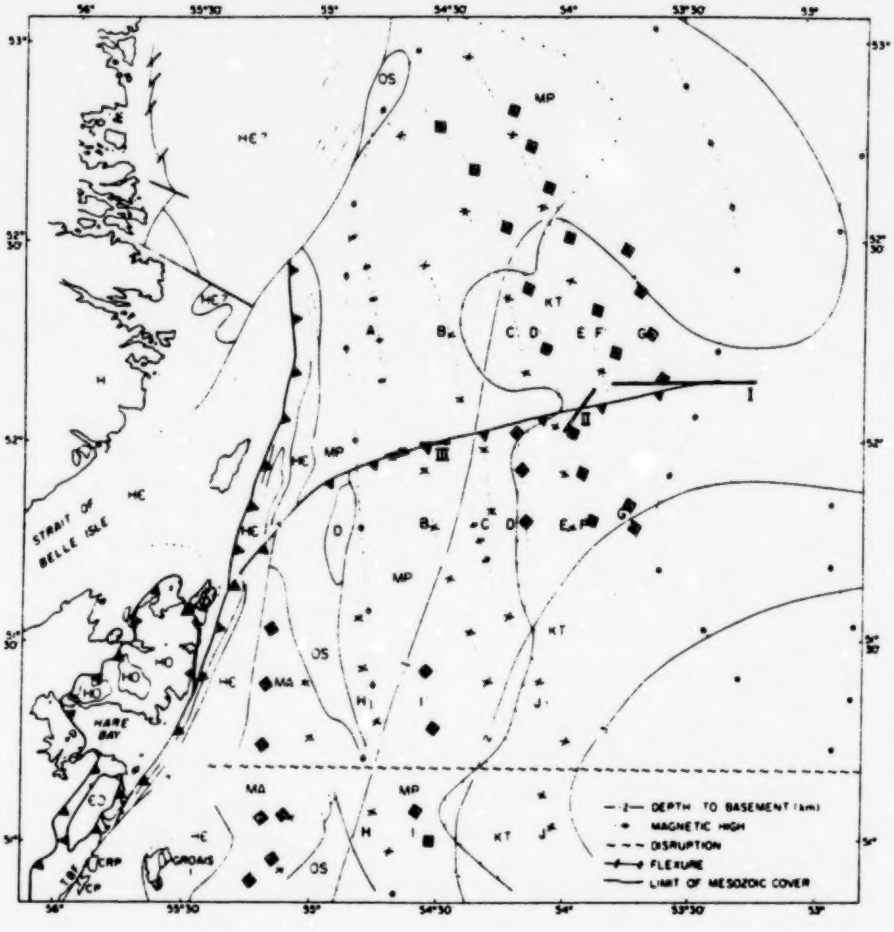

56°
55°30'
55°
54°30'
54°
53°30'
53°
53°
52°30'
52°
51°30'
51°
HЄ?
OS
MP
KT
A
B
C
D
E
F
G
I
II
III
H
HЄ
MP
D
STRAIT OF BELLE ISLE
HO
HARE BAY
OS
MA
H
I
J
KT
CO
MA
MP
H
I
KT
J
HЄ
CRP
CP
TBF
GROAIS I.
OS
DEPTH TO BASEMENT (km)
MAGNETIC HIGH
DISRUPTION
FLEXURE
LIMIT OF MESOZOIC COVER

FIGURE 48. Geology of the southern Labrador Shelf. Letters A to J identify those folds within the Mississippian-Pennsylvanian strata that correlate across the thrust/transcurrent fault at approximately 52°N and the discontinuity at approximately 51°N. TBF = Taylors Brook fault; CP = Conche Peninsula; CRP = Cape Rouge Peninsula; H = Helikian and older; HC = Hadrynian and Cambrian; HO = Hadrynian to Middle Ordovician; CO = Upper Cambrian to Middle Ordovician; OS = Ordovician or Silurian; D = Devonian; MA = Mississippian; MP = Mississippian and Pennsylvanian; KT = Cretaceous and Tertiary. Heavy line with teeth = thrust; dash-dot ornament = fold axis in Hadrynian terranes; thin continuous dotted line = possible extension of Hadrynian terranes in the Strait of Belle Isle; dash and square line = anticline; dash and cross line = syncline; the cover is located east of the boundary between cover and basement (after Lefort and Haworth 1984).

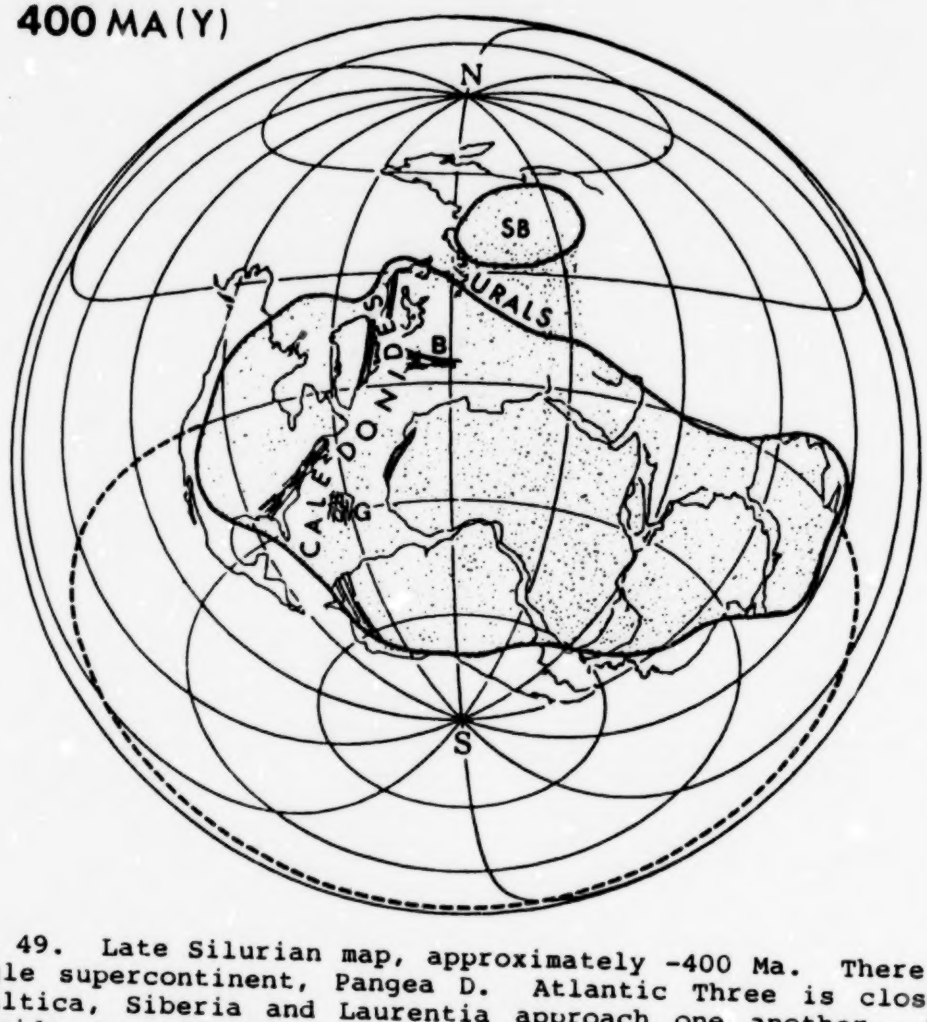


FIGURE 49. Late Silurian map, approximately -400 Ma. There is a single supercontinent, Pangea D. Atlantic Three is closed, and Baltica, Siberia and Laurentia approach one another. The Caledonide superfoldbelt is indicated, and B is the central European foldbelt especially in Bohemia (after Morel and Irving 1978).

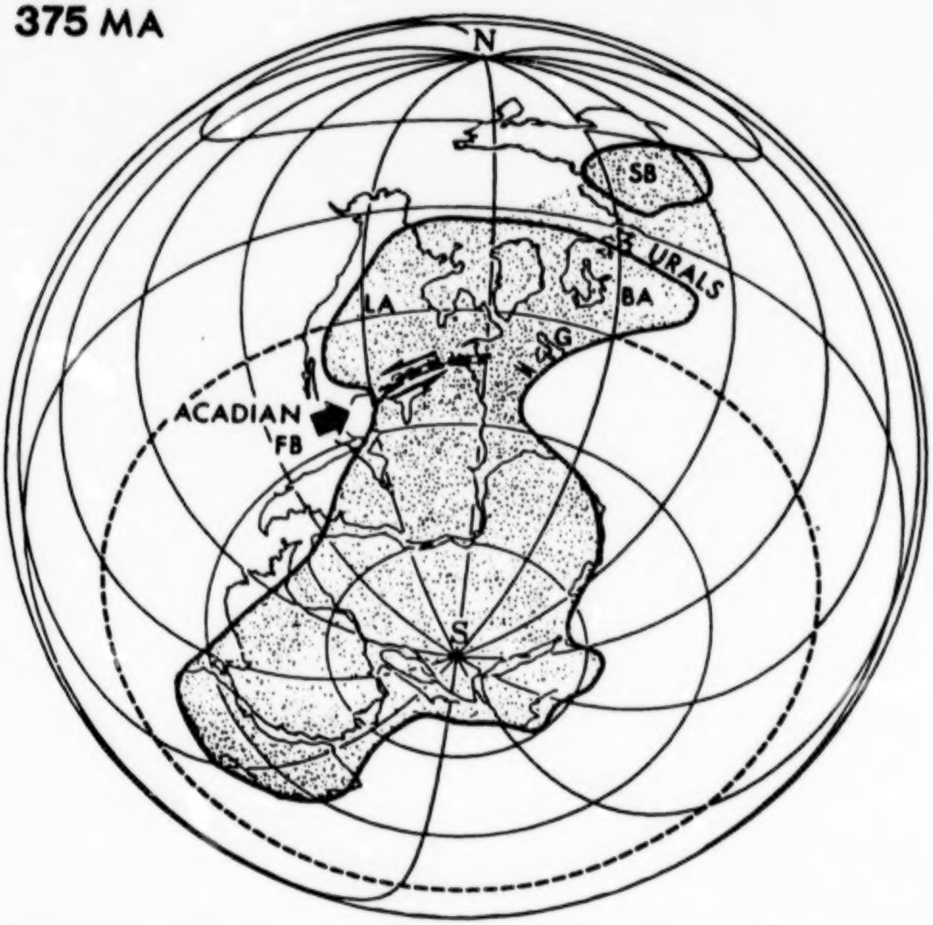

375 MA
N
SB
URALS
LA
BA
G
ACADIAN
FB
S

FIGURE 50. Early to Middle Devonian map, approximately -375 Ma, Pangea C. Laurasia is now assembled and Gondwana (with at least part of the British Isles) rotates sinistrally with respect to Laurasia bringing the British Isles into their present position relative to Baltica (after Morel and Irving 1978).

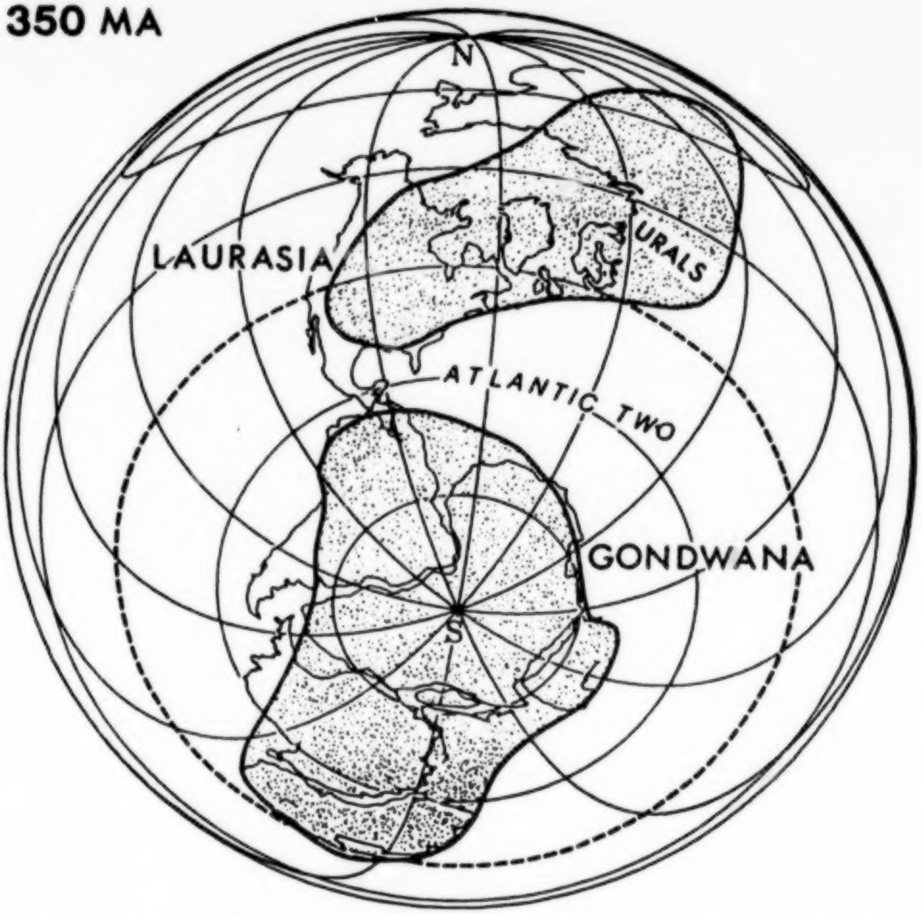

350 MA
N
LAURASIA
URALS
ATLANTIC TWO
GONDWANA
S

FIGURE 51. Late Devonian map, approximately -350 Ma. Pangea C splits forming Atlantic Two (after Morel and Irving 1978).

325 MA

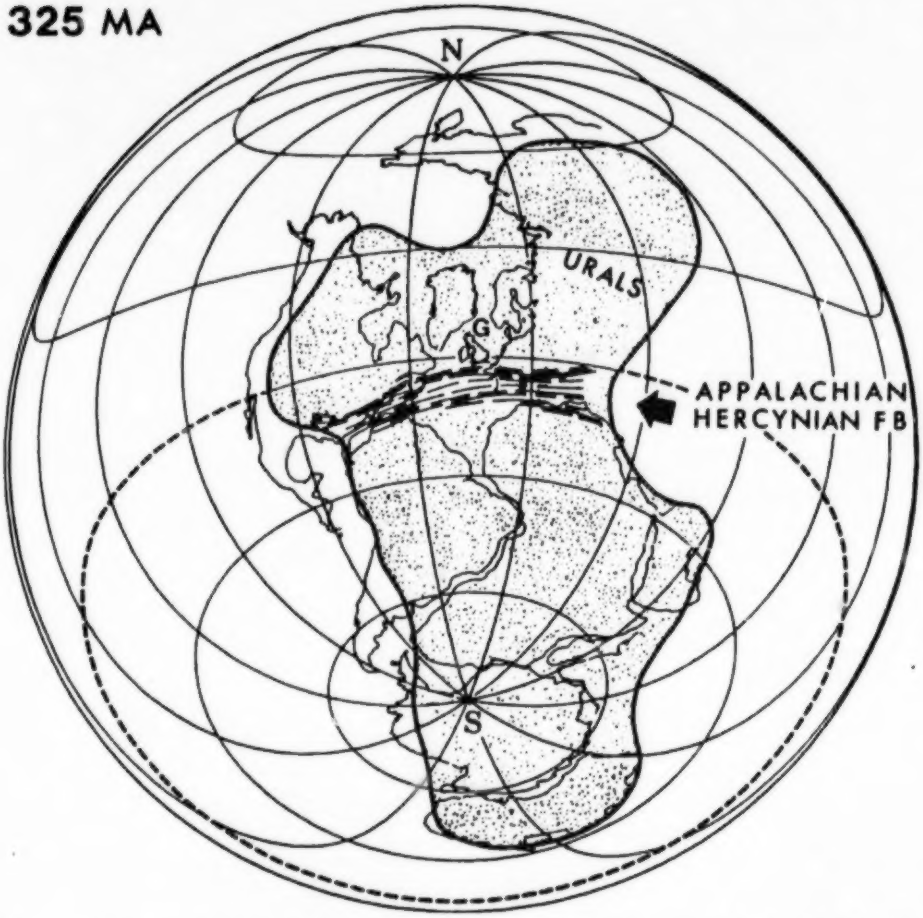

N
URALS
G
APPALACHIAN
HERCYNIAN FB
S

FIGURE 52. Middle Carboniferous map, approximately -325 Ma. Atlantic Two closes, forming Pangea B and the Hercynian superfoldbelt (after Morel and Irving 1978).

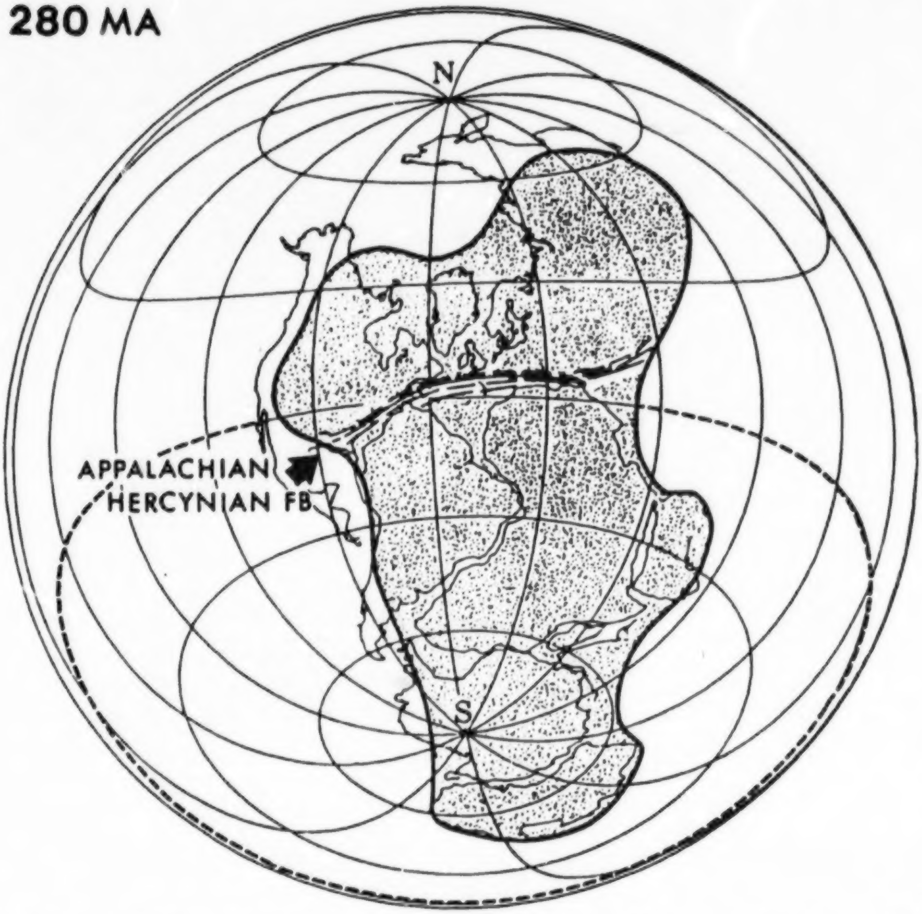

280 MA
N
S
APPALACHIAN
HERCYNIAN FB

FIGURE 53. Early Permian map, approximately -280 Ma. Pangea B, modified from Irving (1977) (after Morel and Irving 1978).

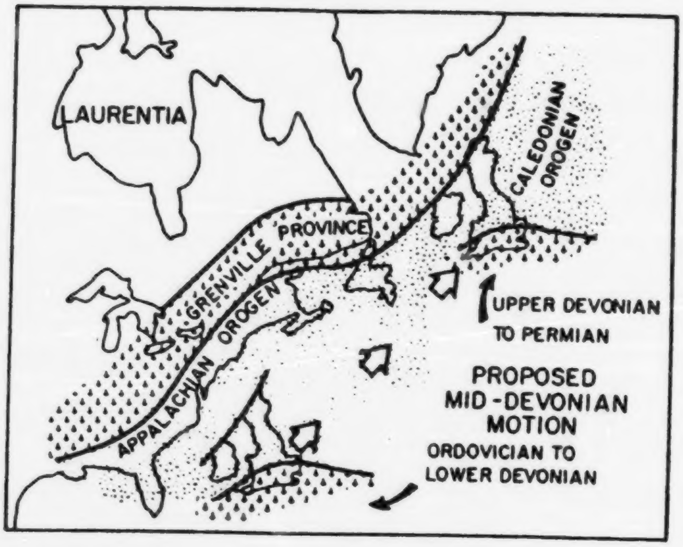

LAURENTIA
GRENVILLE PROVINCE
APPALACHIAN OROGEN
CALEDONIAN OROGEN
UPPER DEVONIAN TO PERMIAN
PROPOSED MID-DEVONIAN MOTION
ORDOVICIAN TO LOWER DEVONIAN

FIGURE 54. Proposed mid-Paleozoic transcurrent motion. During the Paleozoic, Britain apparently occupied two different positions relative to North America. During Ordovician and Silurian-Lower Devonian times, Britain was in a more southerly latitude than that occupied during the Upper Devonian. The motion between the two positions appears to have been essentially transcurrent and to have taken place approximately at the beginning of the Middle Devonian (after Morris 1976).

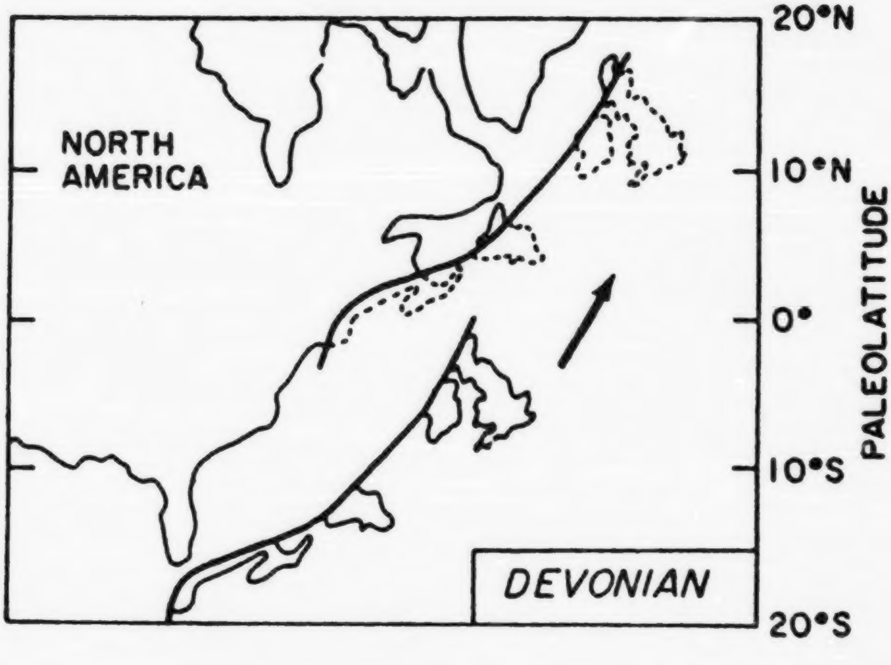

NORTH
AMERICA
20°N
10°N
0°
10°S
20°S
PALEOLATITUDE
DEVONIAN

FIGURE 55. Paleogeographic sketch of North America in the Devonian showing the position of the New England-Maritime region, along with parts of the British Isles, with respect to the North American craton. The paleolatitude framework is based on the mean Devonian pole position for each area. The arrow shows the inferred sense of motion during the Carboniferous which brought the Maritime-New England-British Isles area to the position shown by the dashed outline (after Kent and Opdyke 1978).

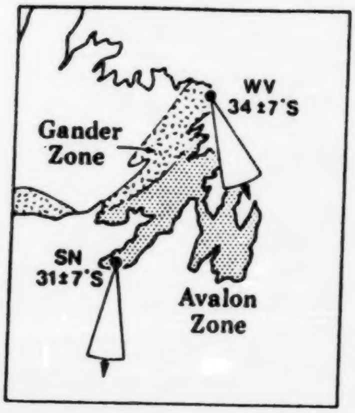

WV
34±7°S
Gander Zone
SN
31±7°S
Avalon Zone

FIGURE 56a. Paleolatitudes and rotations determined from Late Devonian rocks of southeastern Newfoundland. The arrows point to paleosouth. SN = the N magnetization of the St. Lawrence Pluton; WV = the southeasterly magnetization of the Wesleyville dikes (after Irving and Strong 1985).

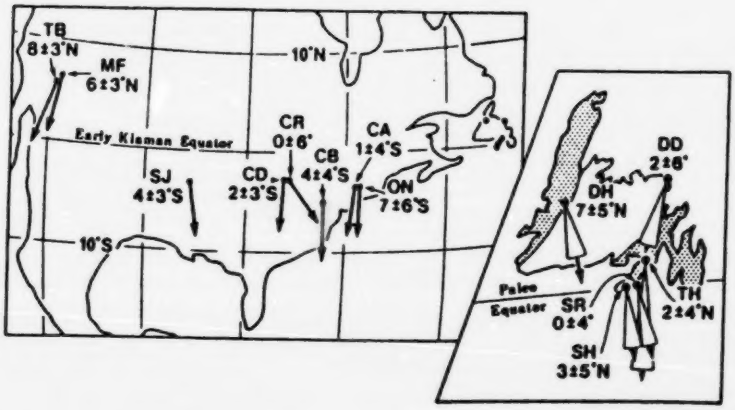

TB
8±3°N
MF
6±3°N
10°N
Early Kiaman Equator
CR
0±6°
CA
1±4°S
CB
4±4°S
SJ
4±3°S
CD
2±3°S
ON
7±6°S
10°S
DD
2±8°
DH
7±5°N
Paleo Equator
SR
0±4°
TH
2±4°N
SH
3±5°N

FIGURE 56b. Paleolatitudes and rotations observed in Middle and Upper (mainly upper) Devonian rocks of cratonic North America compared with the early Kiaman grid. In the inset, overprints observed in Carboniferous and Upper Devonian rocks of Newfoundland are shown. Note how well they accord with the position of the early Kiaman paleoequator. The western Newfoundland platform and the Avalon Zone are shaded (after Irving and Strong 1985).

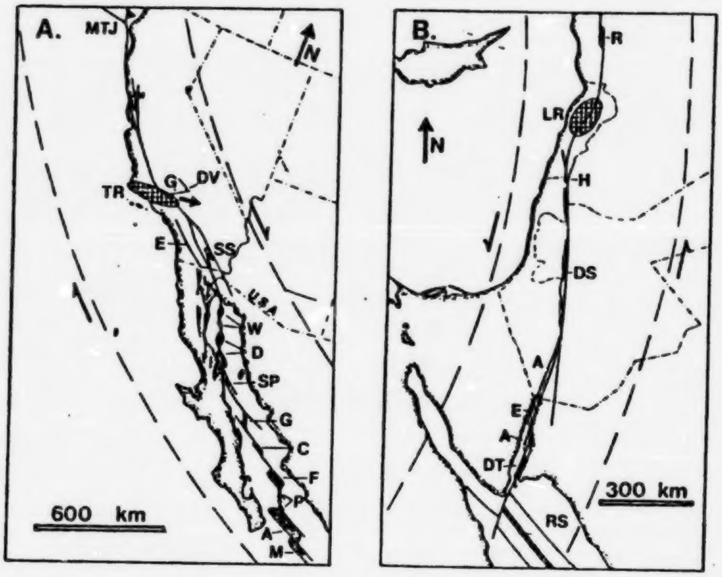


FIGURE 57. Examples of pull-apart basins found within long strike-slip boundaries between rigid continental plates. A. Pacific North America Plate Boundary Zone; dashed lines are theoretical interplate slip lines and abbreviations are: MTJ = Mendocino Tripple Junction; TR = Transverse Ranges push-up block (shown in cross hatching) along dextral San Andreas Fault Zone; DV = Death Valley Basin; G = sinsitral Garlock Fault Zone forming the northern edge of the triangular Mohave Block (black arrow shows general direction of block displacement) E = Lake Elsinore Basin along Elsinore Fault Zone; SS = Salton Sea pull-apart area at a right-step between dextral San Andres and Imperial Fault Zones; W = Wagner Basin (separated by a short transform fault) in northern Gulf of California; D = Delfin Basin (separated by a short transform); SP = San Pedro Martir Basin; G = Guaymas Basin (separated by a short transform); C = Carmen Basin; F = Farallon Basin; P = Pescadero Basin Complex (separated by several short transforms); A = Alarcon Basin; M = Mazatlan Basin. Many smaller pull-aparts are omitted from compilation map. B. Arabia and Sinai (Levant) Plate Boundary Zone - dashed lines are theoretical interplate slip lines and abbreviations are: R = Er Rharb (Gharb) Basin; LRT = Lebanon Ranges push-up block (shown in cross hatching) along Sinistral Dead Sea Fault Zone; H = Hula Basin; DS = Dead Sea Basin; A = Arava Fault Trough; E = Elat Basin in northern Gulf of Aqaba (Elat); A = Arnona-Aragonese Basin; DT = Dakar-Tiran Basin; RS = Red Sea. Many smaller pull-aparts are omitted from compilation map (modified after Mann et al. 1983).

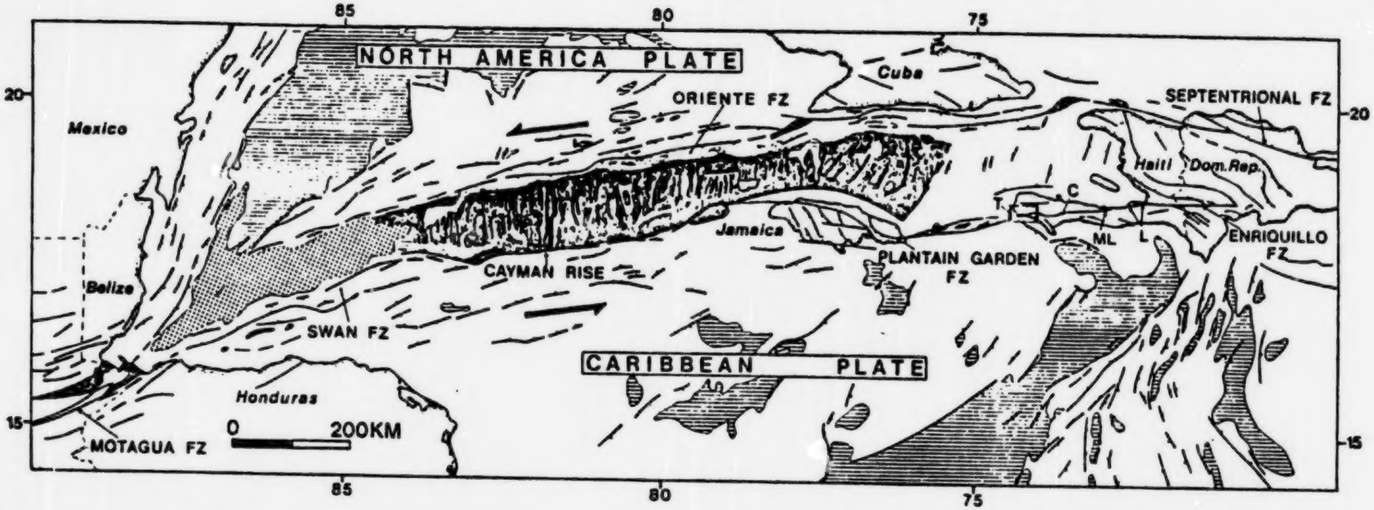

85
80
75
20
15
NORTH AMERICA PLATE
CARIBBEAN PLATE
Mexico
Belize
Honduras
Cuba
Jamaica
Haiti
Dom.Rep.
ORIENTE FZ
SEPTENTRIONAL FZ
ENRIQUILLO FZ
PLANTAIN GARDEN FZ
CAYMAN RISE
SWAN FZ
MOTAGUA FZ
T
C
ML
L
0
200KM

FIGURE 58. Regional setting of active pull-apart basins formed by sinistral strike-slip motion between the North American and Caribbean plates. Most of the grey areas shown are known or inferred pull-aparts at left-steps in either the Setpentrional-Oriente-Swan-Motagua Fault Zones of the Enriquillo-Plantain Garden Fault Zone. The map pattern of basins north of the Motagua Fault Zone in Central America does not indicate a simple pull-apart origin as suggested by Aydin and Nur (1982). The 1400 km long Cayman Trough, the world's longest active pull-apart formed by extension and seafloor spreading at the 100 km long Cayman Rise. Much younger and smaller pull-aparts occur along a 400 km long segment of the Enriquillo-Plantain Garden Fault Zone between eastern Jamaica and western Haiti. Abbreviations for Haitian localities are: L = fault segment south of Leogane; ML = Mirogoane Lakes (detailed map shown in Figure 66A); C = Clonard Basin (detailed map shown in Figure 76); and T = Tiburon Fault Segment. Most of the clastic sediment derived from Central America or push-up blocks like the islands of Jamaica and Hispaniola (Haiti and the Domincan Republic) bypass the Cayman Trough (horizontal ruled areas represent ponded turbidites; dotted area represents proximal submarine fan deposits) (after Mann, et al. 1983).

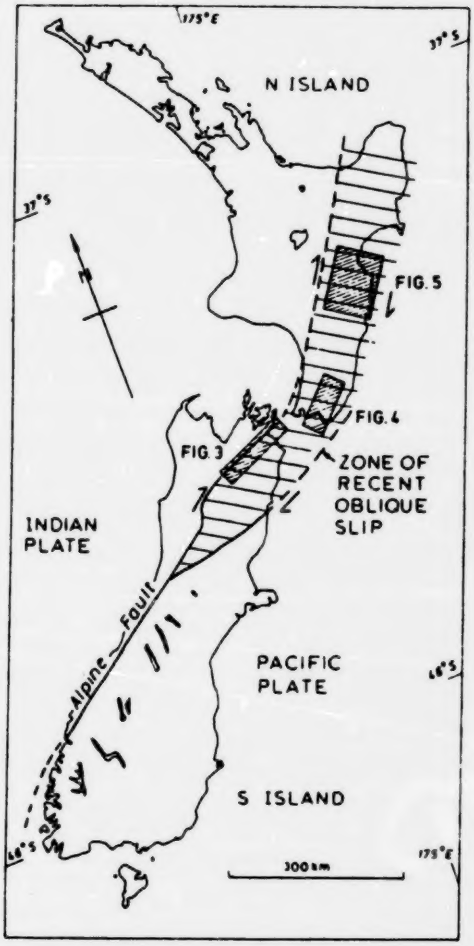

175°E
37°S
N ISLAND
37°S
N
FIG. 5
FIG. 4
FIG. 3
ZONE OF RECENT OBLIQUE SLIP
INDIAN PLATE
Alpine Fault
PACIFIC PLATE
46°S
S ISLAND
46°S
175°E
300 km

FIGURE 59. Map of New Zealand to show the zone of recent oblique-slip (after Ballance 1980).

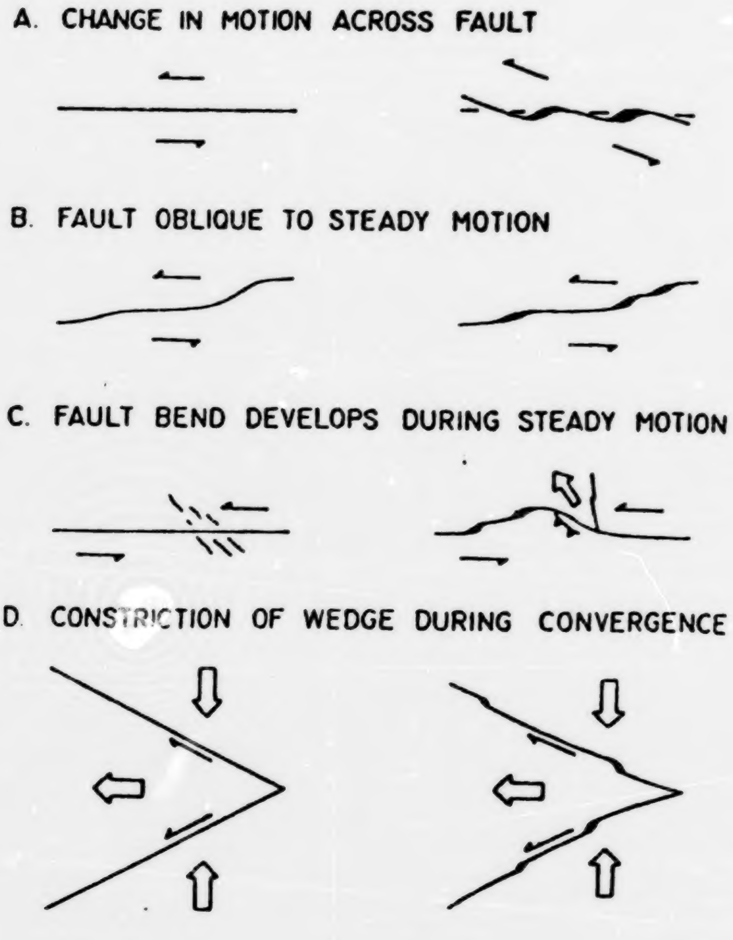

A. CHANGE IN MOTION ACROSS FAULT
B. FAULT OBLIQUE TO STEADY MOTION
C. FAULT BEND DEVELOPS DURING STEADY MOTION
D. CONSTRICTION OF WEDGE DURING CONVERGENCE

FIGURE 60. Possible tectonic mechanisms for the divergence between the interplate slip vector and strike-slip fault trace. Divergence leads to pull-apart basin nucleation (after Mann et al., 1983).

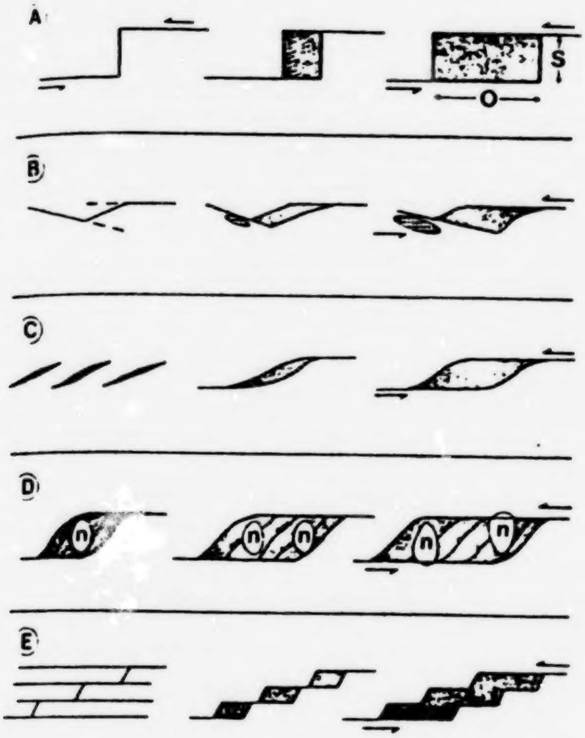


FIGURE 61. Previous models of pull-apart basin development. A. Simple model of pull-apart opening between left-stepping and sinistral "master" strike-slip faults; master fault separation (S) or basin width remains constant; master fault overlap (O) or basin length increases with strike-slip offset. B. Modification of simple model based on detailed mapping of active pull-aparts; opening across an oblique median fault and along non-parallel master faults results in an extensional gap on one side of the basin and a compressional overlap or bulge (shown in cross hatching) on the other. C. Deformational pattern produced in shear box experiments suggested pull-aparts nucleate on en echelon fractures. D. Theoretical model of deformation in pull-aparts based on the elastic dislocation theory; "n" designates areas of predicted normal faulting. E. Coalescing of adjacent pull-aparts was suggested by Aydin and Nur (1982) as one explanation for widening of pull-aparts with increased offset (after Mann et al. 1983).

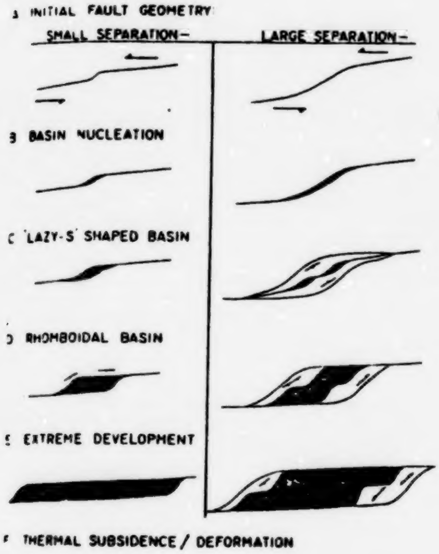

A INITIAL FAULT GEOMETRY
SMALL SEPARATION–
LARGE SEPARATION–
B BASIN NUCLEATION
C 'LAZY-S' SHAPED BASIN
D RHOMBOIDAL BASIN
E EXTREME DEVELOPMENT
F THERMAL SUBSIDENCE / DEFORMATION

FIGURE 62. Continuum model of pull-apart basin development generalized from structural, sedimentary, and thermal characteristics of well mapped active and ancient pull-aparts. A. Pull-aparts nucleate at releasing fault bends along faults which are oblique to the direction of relative plate motion (indicated by arrows); larger bends or areas of greater strike-slip fault separation will develop into wider basins. B. Spindle-shaped pull-aparts nucleate on releasing bends. C. Continued offset produces "lazy S" sedimentary basin geometry; extension across bends with large fault separation may be relayed by two or more buried pull-aparts (shown in grey). D. Continued offset of lazy S-shaped basin produces rhomboidal or "rhomb graben" basin geometry; buried pull-aparts at bends with large fault separation may coalesce to form a basin whose width remains fixed by the original width of the releasing bend. E. With steady offset, rhomboidal basins can develop into long narrow troughs which at some point develop a short spreading ridge and are floored by oceanic crust; distal ends preserve early opening structures. F. Gradually declining thermal subsidence following lithospheric extension at larger pull-aparts results in extensive overlying sedimentary basins similar to those formed above rifts. Deformation in rapidly changing strike-slip environments generally terminates pull-apart development after the basin length triples the width of the initial releasing bend (after Mann et al. 1983).

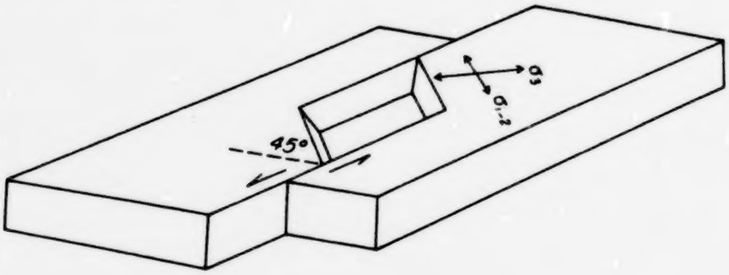


FIGURE 63a. A schematic model of a rhomb graben at the left-slip fault. The vertical strike slip fault becomes an inclined normal fault along the graben whose length exceeds the displacement, and the connecting faults are normal and their strike deviates by c. 45° from the main strike slip, normal to the least principal stress coaxial with the shear stress (after Freund 1982).

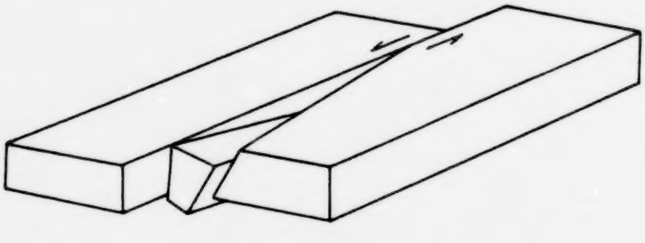


FIGURE 63b. A schematic model of wedge graben which occurs between a strike slip fault and a branch fault which deviates from the main fault by an acute angle against the direction of shear. The branch fault is normal, but the dip of the main fault remains unaltered. The deepest part occurs at the tip (after Freund 1982).

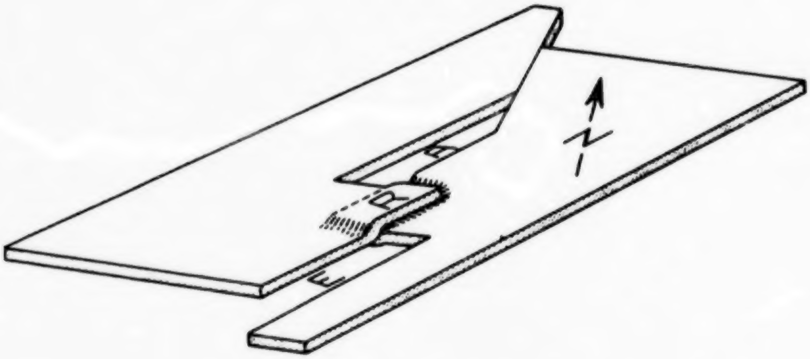


FIGURE 64a. A model proposed to explain the contemporaneous creation of the Ruwenzori (R) uplift with the rifting of the Albert (A) and Edward (E) grabens by oblique motion across a step-like fault configuration (after Freund 1982).

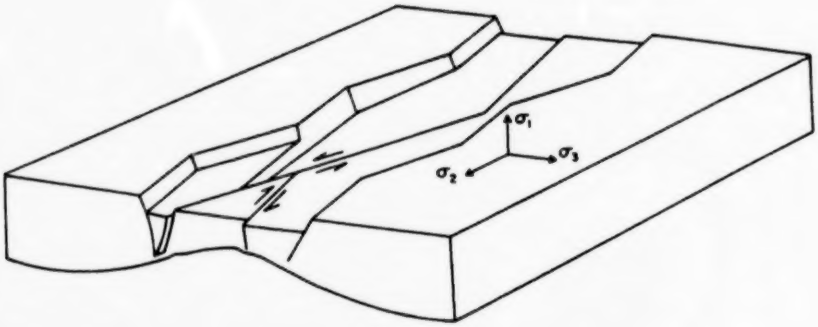


FIGURE 64b. Zigzag pattern of normal faults in rift valleys and rare strike slip faults associated with the rifting as they appear in clay models and in several rifts (after Freund 1982).

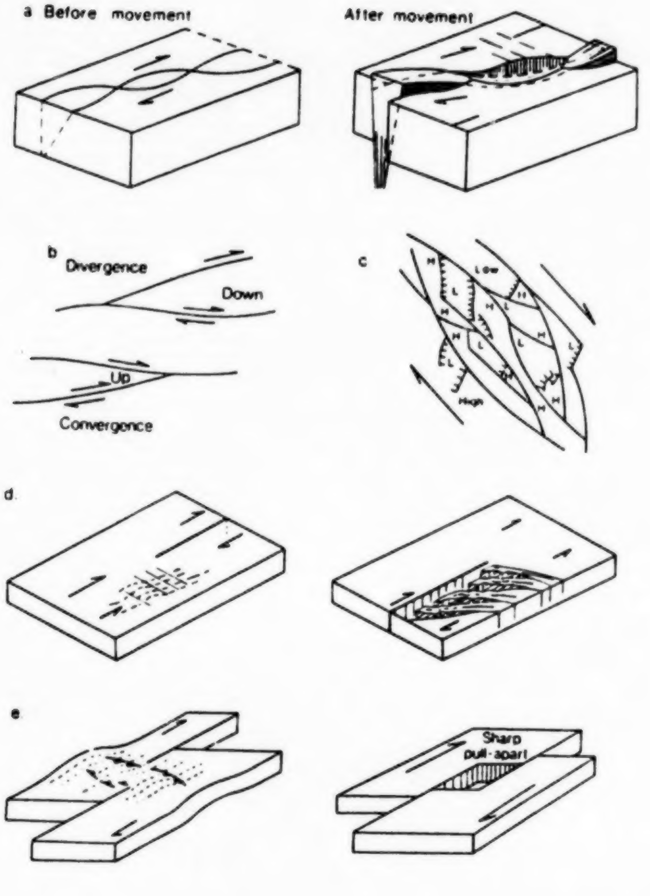

a Before movement
After movement
b
Divergence
Down
Up
Convergence
c
Low
High
H
L
d.
e
Sharp pull-apart

FIGURE 65. Types of strike-slip fault patterns that produce extensional subsiding basins and compressional, uplifted blocks: (a) curbed fault trace, (b) divergent and convergent fault patterns, (c) anastomosing faults, (d) fault terminations, (e) side-stepping faults (after Crowell 1974; Reading 1980).

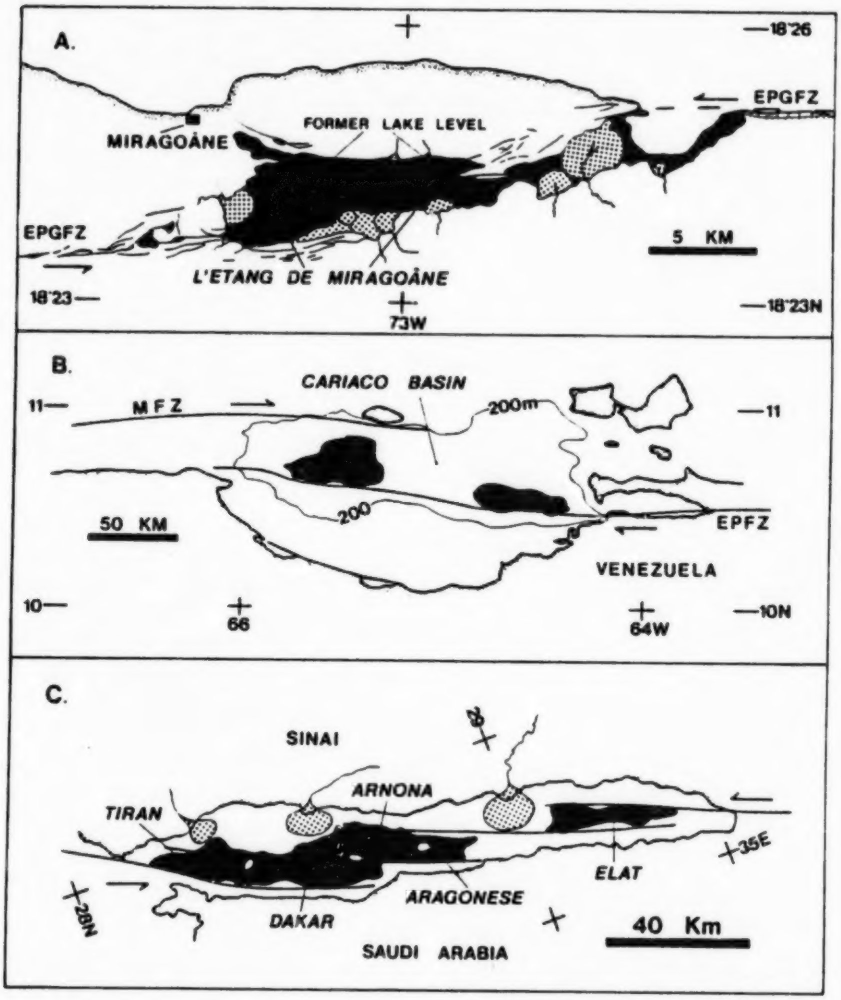

A.
18°26
EPGFZ
FORMER LAKE LEVEL
MIRAGOÂNE
EPGFZ
5 KM
L'ETANG DE MIRAGOÂNE
18°23
73W
18°23N
B.
CARIACO BASIN
11
MFZ
200m
11
50 KM
200
EPFZ
VENEZUELA
10
66
64W
10N
C.
SINAI
29
ARNONA
TIRAN
ELAT
35E
28N
ARAGONESE
DAKAR
40 Km
SAUDI ARABIA

FIGURE 66. Examples of active rhomboidal pull-apart basins. A. Fault and recent sediment map of the Mirogoane Lakes (L'Etang de Mirogoane) Basin at left-step of sinistral Enriquillo-Plantain Garden Fault Zone (EPGFZ) in Haiti (see Figure 58 for location). Black areas represent fresh-water lakes; grey area represents basin alluvium; grey and stippled area represents former extent of lakes; stippled areas represent alluvial fans. B. Fault and bathymetric map of Cariaco Basin at a right-step between the dextral Moron (MFZ) and El Pilar (EPFZ) Fault Zones, Venezuelan Borderlands. Grey area represents water depths from 100 to 1400 m; black represents depths greater than 1400 m. C. Fault, bathymetric and recent sediment map of pull-aparts at left-steps of the sinistral Dead Sea Fault Zone in the Gulf of Aqaba (Elat) (see Figure 57B for location). In the Elat Basin, black represents water depths greater than 900 m; in the Arnona-Aragonese and Dakar-Tiran Basins, black represents water depths from 1300 to 1800 m. Stippled areas represent fan delta complexes (after Mann *et al*. 1983).

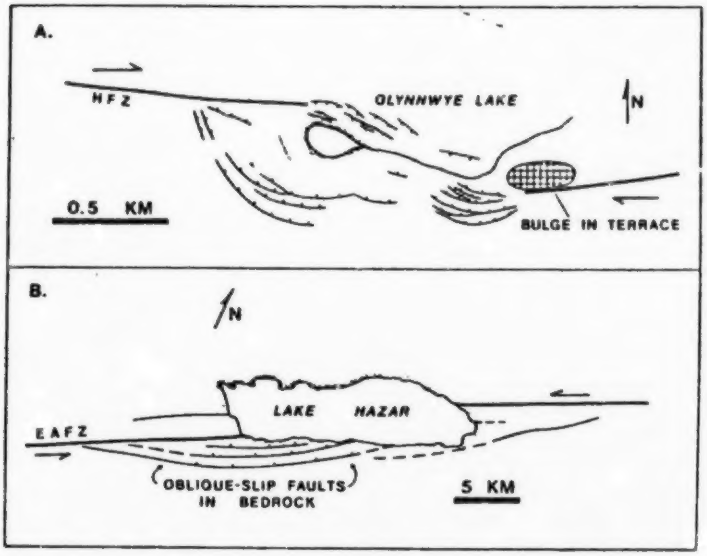

A.
HFZ
GLYNNWYE LAKE
N
0.5 KM
BULGE IN TERRACE
B.
N
LAKE HAZAR
EAFZ
OBLIQUE-SLIP FAULTS IN BEDROCK
5 KM

FIGURE 67. A. Map of active Glynnwye Lake Basin, New Zealand. Heavy lines are traces of Hope Fault Zone (HFZ). B. Map of active Lake Hazar Basin, Turkey. Heavy lines are traces of East Anatolian Fault Zone (EAFZ) (after Mann et al. 1983).

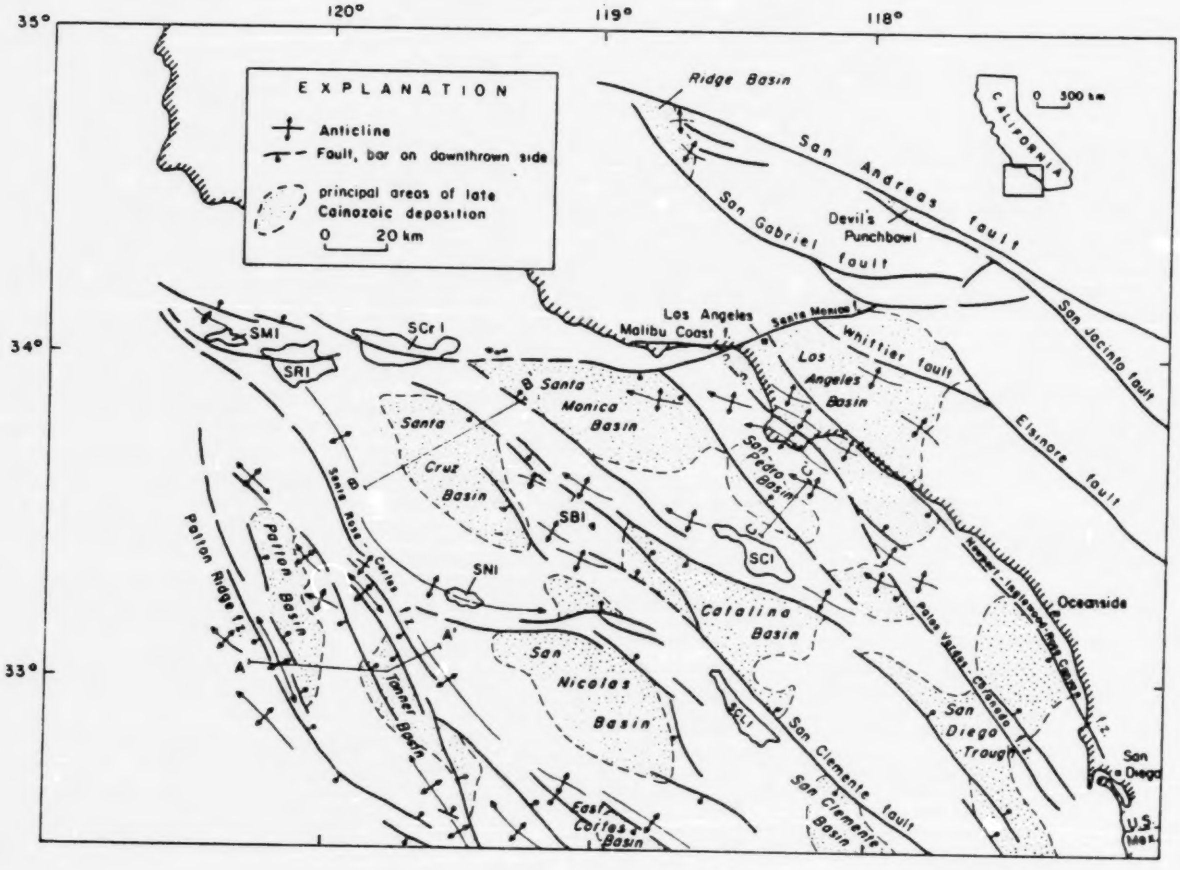

35°
120°
119°
118°
34°
33°
EXPLANATION
Anticline
Fault, bar on downthrown side
principal areas of late Cainozoic deposition
0 20 km
Ridge Basin
San Andreas fault
San Gabriel fault
Devil's Punchbowl
San Jacinto fault
CALIFORNIA
0 300 km
Los Angeles
Malibu Coast f.
Santa Monica f.
Whittier fault
Los Angeles Basin
Elsinore fault
SMI
SCrI
SRI
Santa Monica Basin
Santa Cruz Basin
San Pedro Basin
Santa Rosa - Cortes f.
SBI
SNI
SCI
Patton Ridge f.
Patton Basin
Catalina Basin
Newport - Inglewood - Rose Canyon f.
Oceanside
Palos Verdes - Coronado f.
San Nicolas Basin
Tanner Basin
SCLI
San Clemente fault
San Clemente Basin
San Diego Trough
San Diego
U.S.
Mex.
East Cortes Basin
A
A'
B
B'
C
C'

FIGURE 68. Selected wrench-tectonic elements related to the development of basins in southern California: SMI = San Miguel Island; SRI = Santa Rosa Island; SCrI = Santa Cruz Island; SCI = Santa Catalina Island; SBI = Santa Barbara Island; SNI = San Nicolas Island; SCLI = San Clemente Island. Line A-A', B-B', and C-C' are lines of profiles in Figure 11 of Howell _et al._ (1980) (after Howell _et al._ 1980).

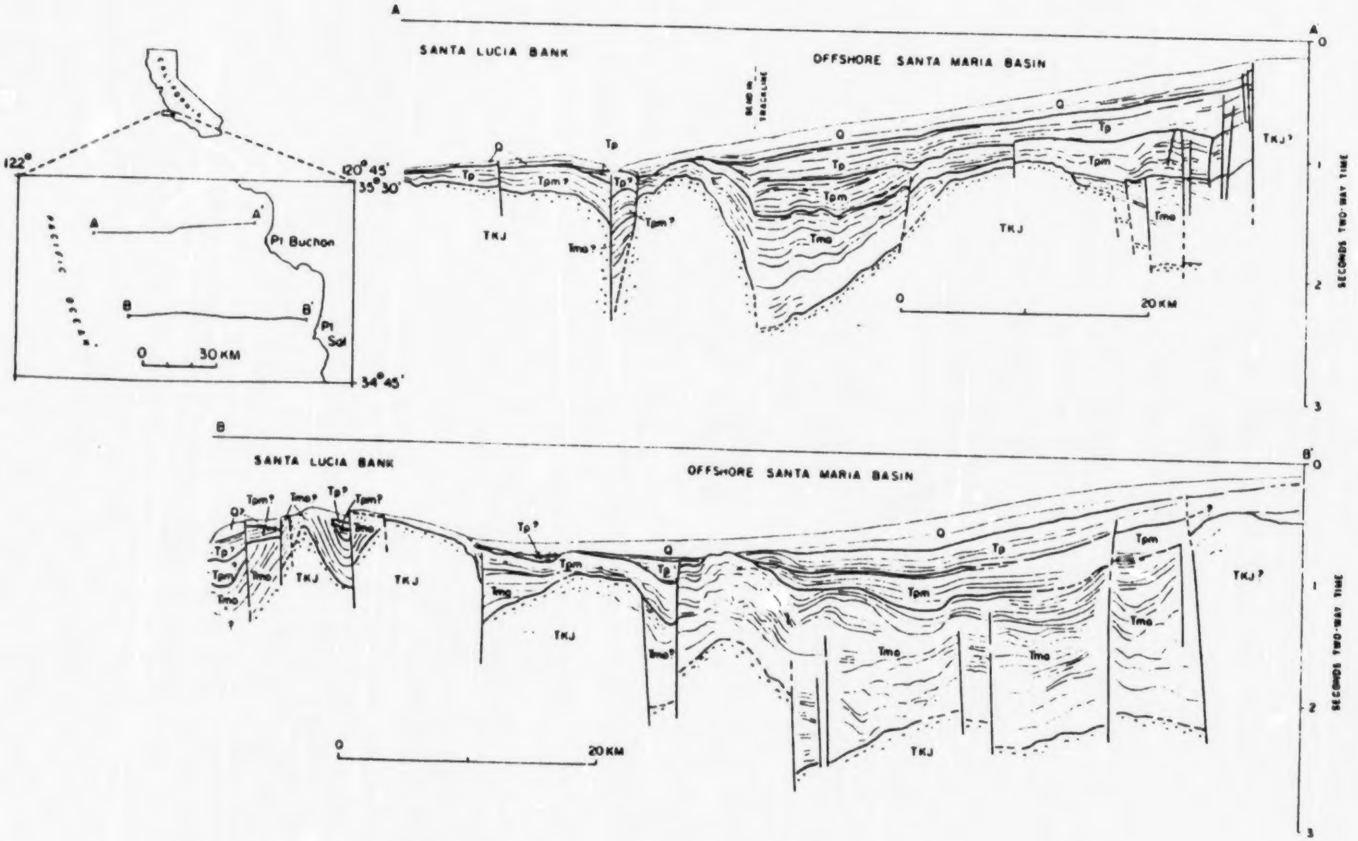

122°
120° 45'
35° 30'
34° 45'
A
A'
B
B'
Pt Buchon
Pt Sal
PACIFIC OCEAN
0 30 KM
SANTA LUCIA BANK
OFFSHORE SANTA MARIA BASIN
BEND IN TRACKLINE
Q
Tp
Tp?
Tpm
Tpm?
Tmo
Tmo?
TKJ
TKJ?
0 20 KM
SECONDS TWO-WAY TIME
0
1
2
3

FIGURE 69. Interpretations from seismic-reflection profiles across the Pacific shelf of central California (vertical exaggeration = 10X). Explanation of symbols: Q = sediments of Pleistocene and Holocene age; Tp = sedimentary rocks of middle and late Pliocene ages; Tpm = sedimentary rocks of late Miocene and early Pliocene age; Tmo = cherty, calcareous and siliceous shale of late Oligocene to middle Miocene age; TKJ = acoustic basement, probably equivalent to the Franciscan assemblage (after Howell et al. 1980).

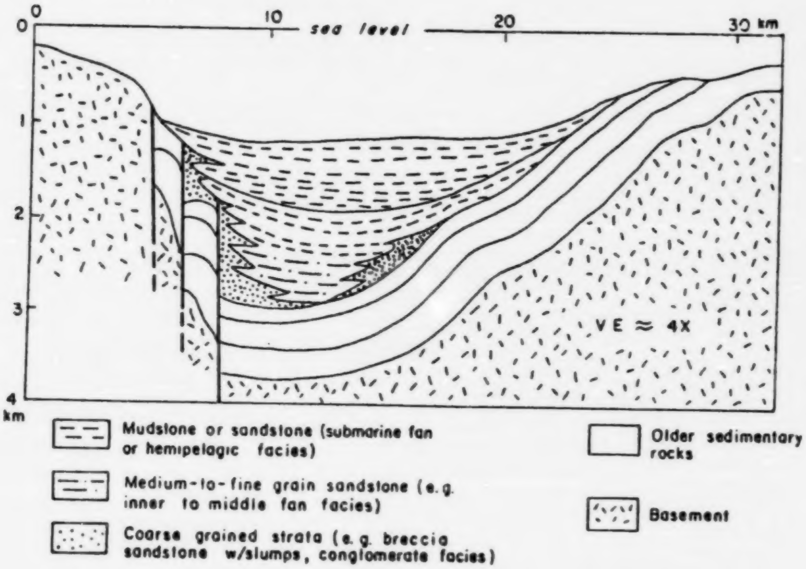

0
10
sea level
20
30 km
0
1
2
3
4
km
VE ≈ 4X
Mudstone or sandstone (submarine fan or hemipelagic facies)
Medium-to-fine grain sandstone (e.g. inner to middle fan facies)
Coarse grained strata (e.g. breccia sandstone w/slumps, conglomerate facies)
Older sedimentary rocks
Basement

FIGURE 70. Stratigraphic relations inferred for structural basins formed within a wrench-tectonic setting of the southern California borderland (after Howell et al. 1980).

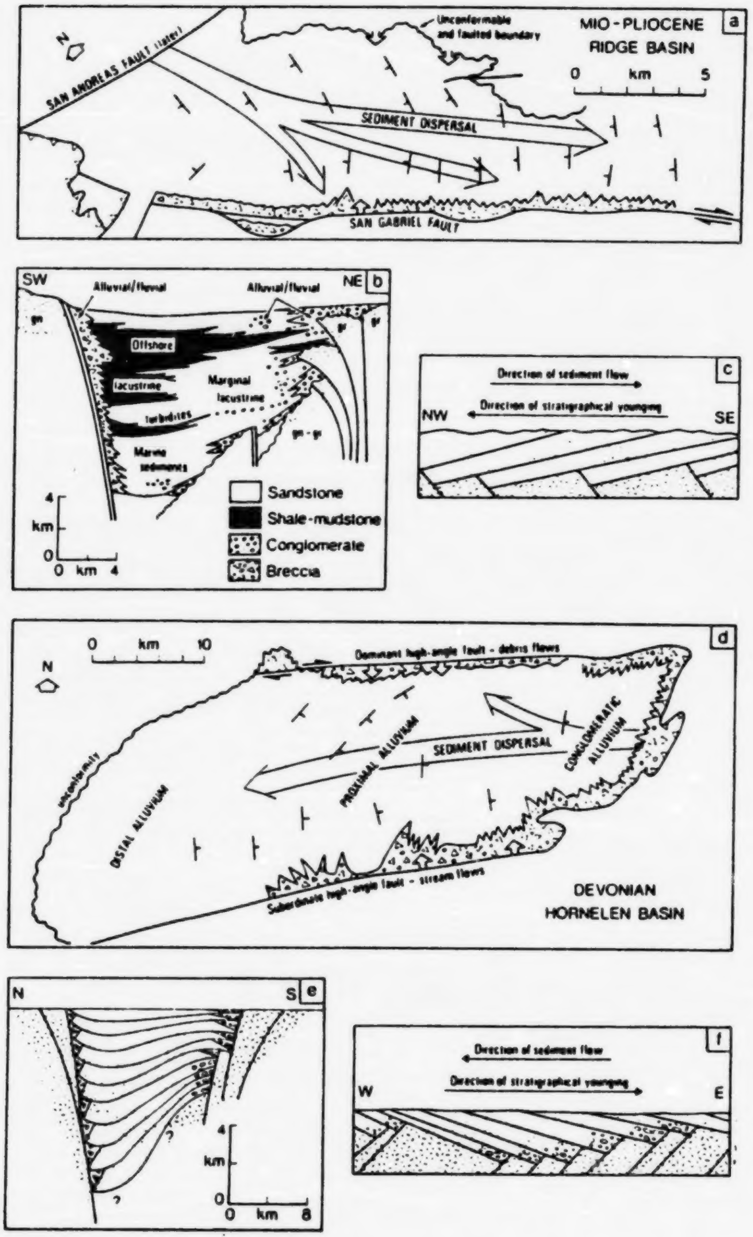

a
MIO-PLIOCENE
RIDGE BASIN
Unconformable and faulted boundary
N
0 km 5
SAN ANDREAS FAULT (later)
SEDIMENT DISPERSAL
SAN GABRIEL FAULT
b
SW
NE
Alluvial/fluvial
Alluvial/fluvial
gn
gr
Offshore
lacustrine
turbidites
Marginal lacustrine
Marine sediments
gn - gr
4
km
0
0 km 4
Sandstone
Shale-mudstone
Conglomerate
Breccia
c
Direction of sediment flow
Direction of stratigraphical younging
NW
SE
d
0 km 10
N
Dominant high-angle fault - debris flows
SEDIMENT DISPERSAL
CONGLOMERATIC ALLUVIUM
PROXIMAL ALLUVIUM
DISTAL ALLUVIUM
unconformity
Subordinate high-angle fault - stream flows
DEVONIAN
HORNELEN BASIN
e
N
S
4
km
0
0 km 8
?
?
f
Direction of sediment flow
Direction of stratigraphical younging
W
E

FIGURE 71. Structural and sedimentary patterns in the Pliocene Ridge Basin, California and the Devonian Hornelen Basin, Norway (after Reading 1980).

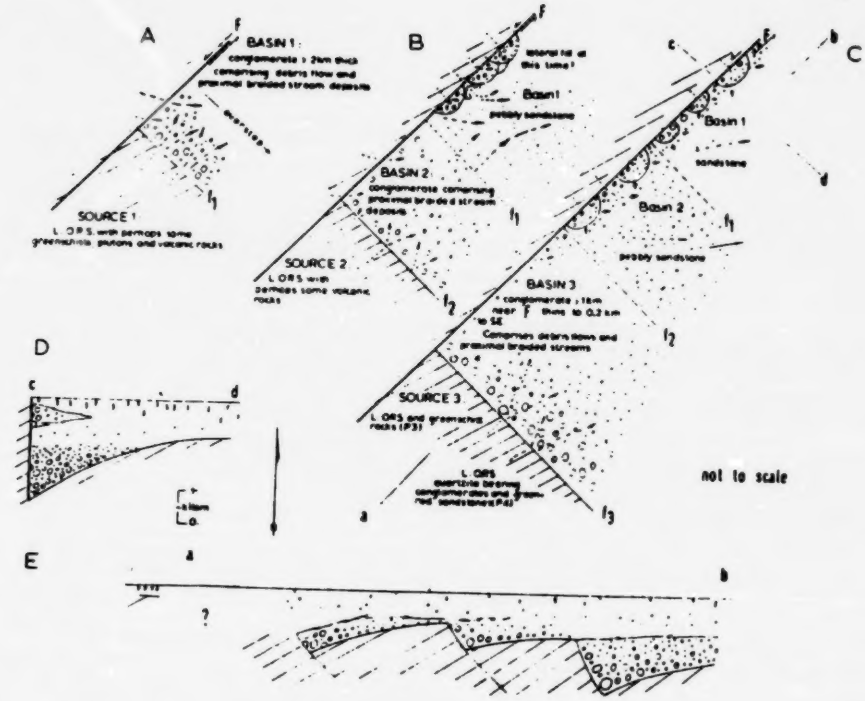

A
F
BASIN 1:
conglomerate > 2km thick
comprising debris flow and
proximal braided stream deposits
f1
SOURCE 1
L. ORS with perhaps some
greenschists, plutons and volcanic rocks
B
lateral fill at
this time?
Basin 1
pebbly sandstone
BASIN 2
conglomerate comprising
proximal braided stream
deposits
f1
SOURCE 2
L. ORS with
perhaps some volcanic
rocks
f2
C
c
b
Basin 1
sandstone
d
Basin 2
f1
pebbly sandstone
BASIN 3
conglomerate, 1km
near F thins to 0.2 km
to SE
Comprises debris flows and
proximal braided streams
f2
SOURCE 3
L. ORS and greenschist
rocks (P3)
L. ORS
quartzite bearing
conglomerates and green-
red sandstones (P4)
a
f3
not to scale
D
c
d
E
a
b
?

FIGURE 72. Synoptic description of sedimentary and stratigraphic details of the Upper Old Red Sandstone rocks, together with a diagrammatic explanation of them. A, B, C shows progressive evolution of basins as the master fracture (F = Highland Bouldary Fault) sinistrally moves to extend the basement on its southeast side. This extension results in faults f_1, f_2, f_3 bounding three basins and giving rise to three sources within the general downthrown margin southeast of F. In C, source 3 has two provenances P_3 and P_4. D and E are sections through C (after Bluck 1980).

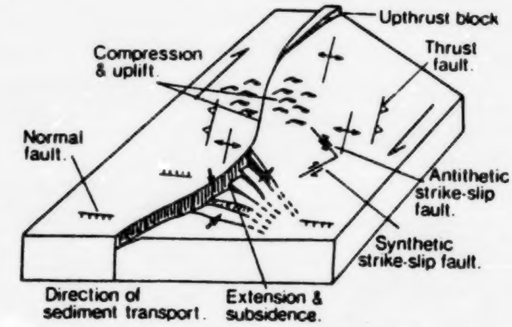
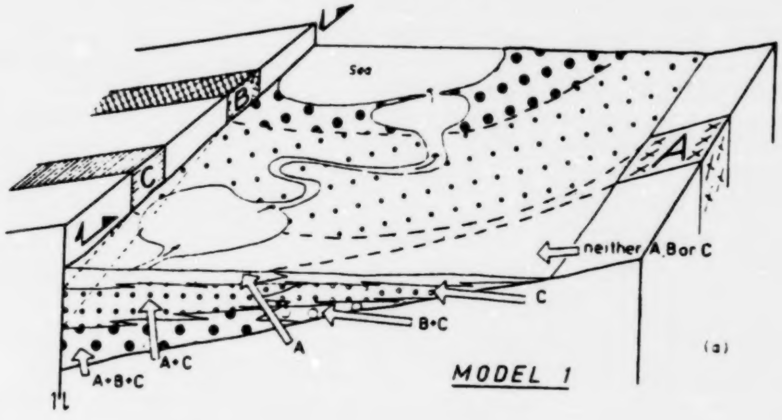

Upthrust block
Compression
& uplift
Thrust
fault.
Normal
fault.
Antithetic
strike-slip
fault.
Synthetic
strike-slip fault.
Direction of
sediment transport.
Extension &
subsidence.

FIGURE 73. Illustration of how the curvature of a dextral strike-slip fault may produce both an extensional basin and a compressional uplifted area from which sediments are eroded (Crowell's 1974 model for the Ridge basin of California). Superimposed on this model is the structrual pattern to be expected from a dextral strike-slip system. Sediment transport is to the right (after Reading 1982).

DRAINAGE IN THE SAME DIRECTION AS STRIKE-SLIP MOTION ON UPLIFTED BLOCK


Sea
B
C
A
neither A,B or C
C
B+C
A
A+C
A+B+C
(a)
MODEL 1

DRAINAGE CONTRARY TO STRIKE-SLIP MOTION ON UPLIFTED BLOCK

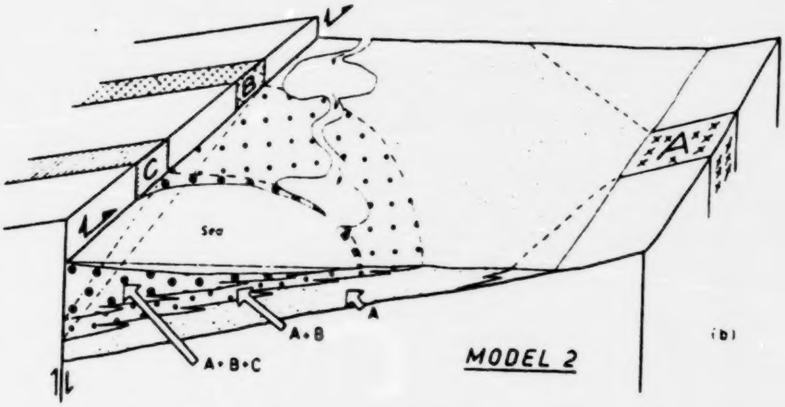
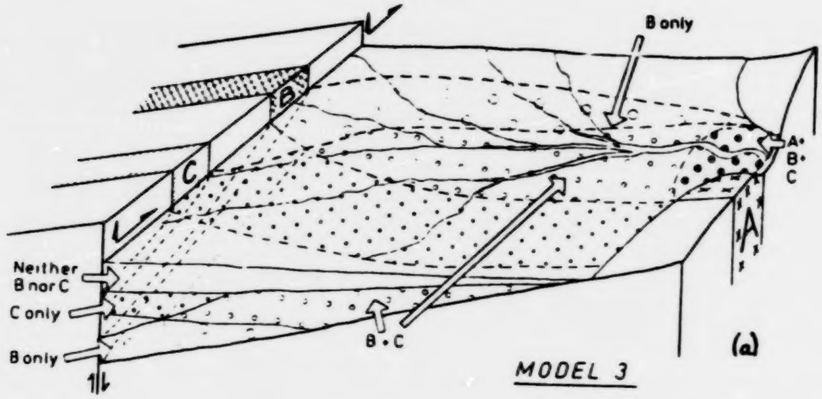

B
C
Sea
A
A+B
A+B+C
A
(b)
MODEL 2

FIGURE 74. Relationships of distinctive petrographic units in alluvial sediments in fault-angle depressions in oblique-slip zones. (a) Drainage in the fault angle depression in the same direction as strike-slip motion on the rising block. (b) Drainage contrary to strike-slip motion on the rising block (after Ballance 1980).

TRANSVERSE DRAINAGE FUNNELLED THROUGH GORGE IN DOWNTHROWN BLOCK


B only
B
C
A+
B+
C
A
Neither B nor C
C only
B only
B+C
(a)
MODEL 3

TRANSVERSE DRAINAGE DIRECT TO SEA OR LAKE

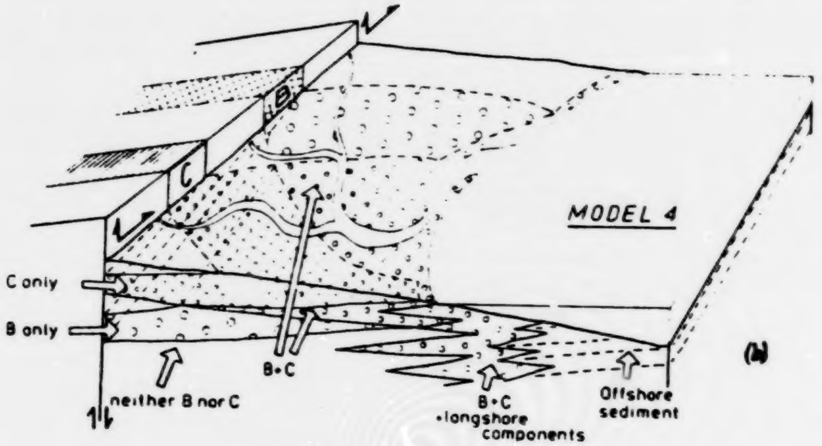

B
C
MODEL 4
C only
B only
B+C
neither B nor C
B+C +longshore components
Offshore sediment
(b)

FIGURE 75. Relationships of distinctive petrographic units in alluvial sediments in fault-angle depressions in oblique-slip zones. (a and b) Drainage transverse to strike-slip motion on the rising block (after Ballance 1980).

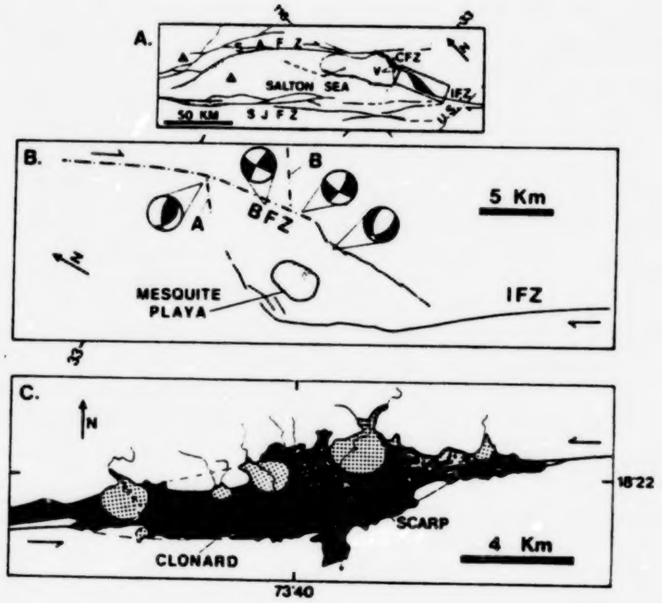


FIGURE 76. Examples of nucleating pull-apart basins along active strike-slip faults. A. Regional setting of pull-aparts in Salton Trough, California: abbreviations are: SAFZ = San Andreas Fault Zone; SJFZ = San Jacinto Fault Zone; CFZ = Calipatria Fault Zone; V = recent volcanic dome; dots indicate areas of Quaternary basin fill; black triangles are peaks about 3 km in elevation in the western part of the Transverse Ranges restraining fault bend; box indicates Salton Group map area shown in Figure 76B. B. Fault map and earthquake focal mechanism solutions of Mesquite Basin between Brawley (BFZ) and Imperial IFZ Fault Zones. Scarps are shown by solid lines; buried faults inferred from seismicity are dashed. C. Fault and sediment map of Clonard Basin, Haiti, based on photointerpretation of 1:40,000 aerial photographs and field observations. Fault scarps are indicated by solid lines; inferred faults are dashed; grey represents basin alluvium; dotted areas are alluvial fans; letter D indicates downthrown side of oblique fault scarp in basin alluvium (after Mann *et al.* 1983).

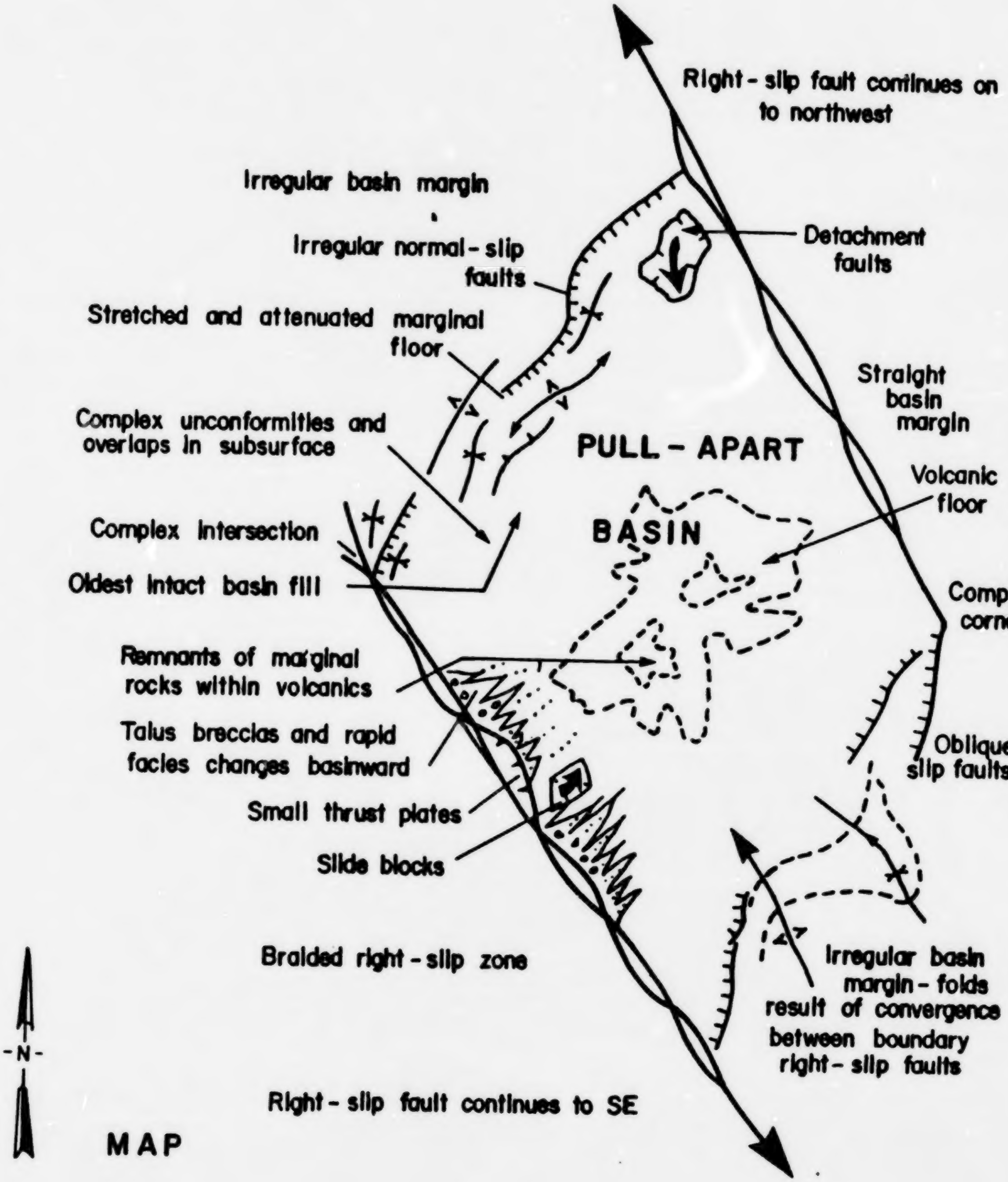
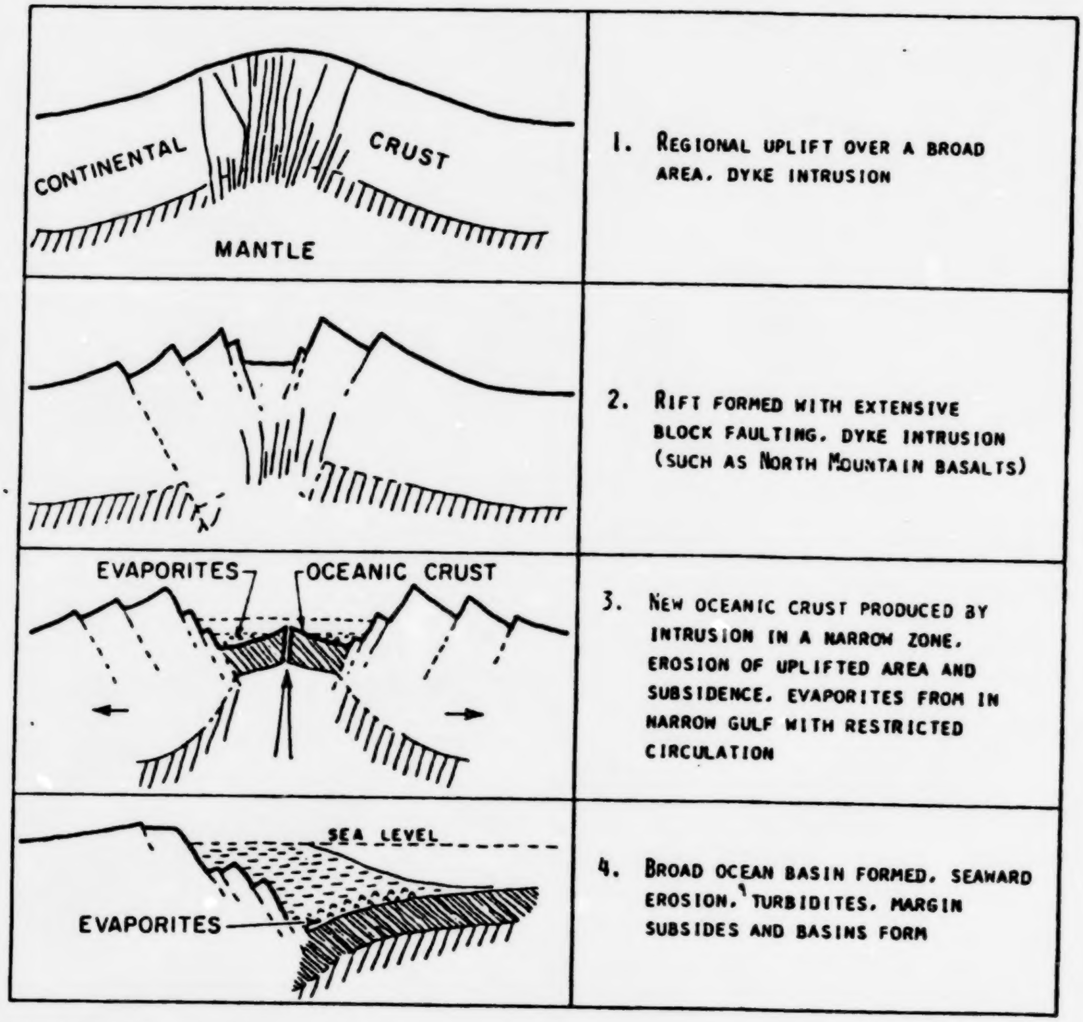

Right-slip fault continues on to northwest
Irregular basin margin
Irregular normal-slip faults
Detachment faults
Stretched and attenuated marginal floor
Straight basin margin
Complex unconformities and overlaps in subsurface
PULL-APART
BASIN
Volcanic floor
Complex intersection
Oldest intact basin fill
Complex corner
Remnants of marginal rocks within volcanics
Talus breccias and rapid facies changes basinward
Oblique-slip faults
Small thrust plates
Slide blocks
Braided right-slip zone
Irregular basin margin-folds result of convergence between boundary right-slip faults
-N-
Right-slip fault continues to SE
MAP

FIGURE 77. Sketch map of idealized pull-apart basin produced by right-stepping en echelon right-lateral strike-slip faults (after Crowell 1974; Rodgers 1980).


CONTINENTAL
CRUST
MANTLE
EVAPORITES
OCEANIC CRUST
SEA LEVEL
EVAPORITES

1. Regional uplift over a broad area. Dyke intrusion

2. Rift formed with extensive block faulting. Dyke intrusion (such as North Mountain basalts)

3. New oceanic crust produced by intrusion in a narrow zone. Erosion of uplifted area and subsidence. Evaporites from in narrow gulf with restricted circulation

4. Broad ocean basin formed. Seaward erosion. Turbidites. Margin subsides and basins form

FIGURE 78. Schematic diagram of process of rifting and opening of an ocean (after King et al. 1975).

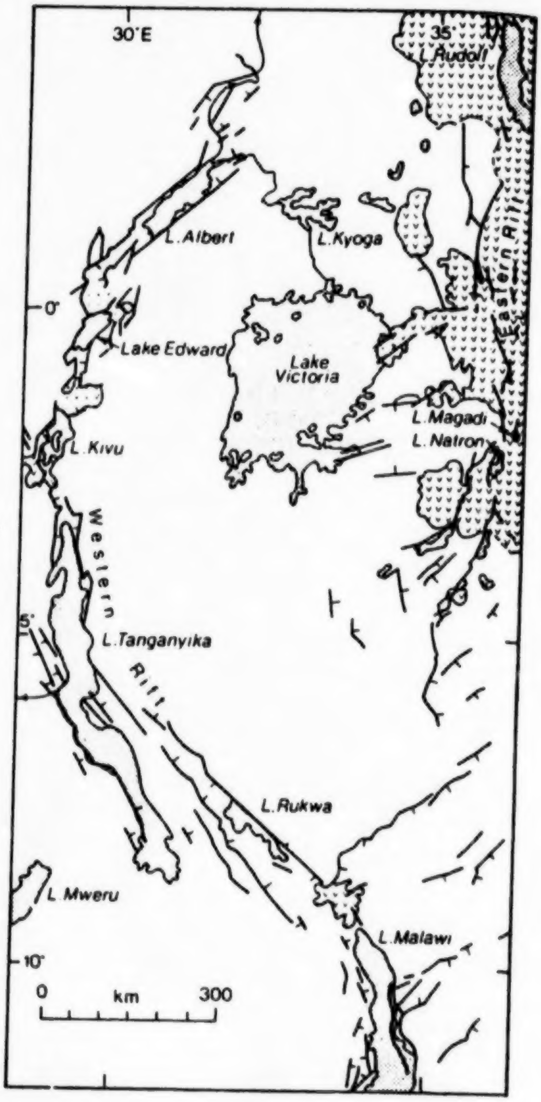

30°E
35°
L.Rudolf
L.Albert
L.Kyoga
0°
Lake Edward
Lake Victoria
L.Magadi
L.Natron
Eastern Rift
L.Kivu
Western Rift
5°
L.Tanganyika
L.Rukwa
L.Mweru
L.Malawi
10°
0 km 300

FIGURE 79. East African rift system showing relationship of lakes to rift tectonics. The location of most of the lakes is governed by faults of the rift system and by volcanoes (e.g., Lake Kivu). Lake Victoria contrasts in being a broad shallow sag basin between the two main rifts. Drainage is mostly away from the rift valleys so that they are starved of clastic sediment. Sedimentation is biologically and chemically controlled. Most of the lakes are fresh (i.e., have a salinity <5% of dissolved salts). Some are alkaline saline lakes (e.g., Lakes Magadi and Natron). Depths range from about 100 m for Lakes Albert and Rudolf to over 1400 m for Lakes Tanganyika and Kivu (after Reading 1982).

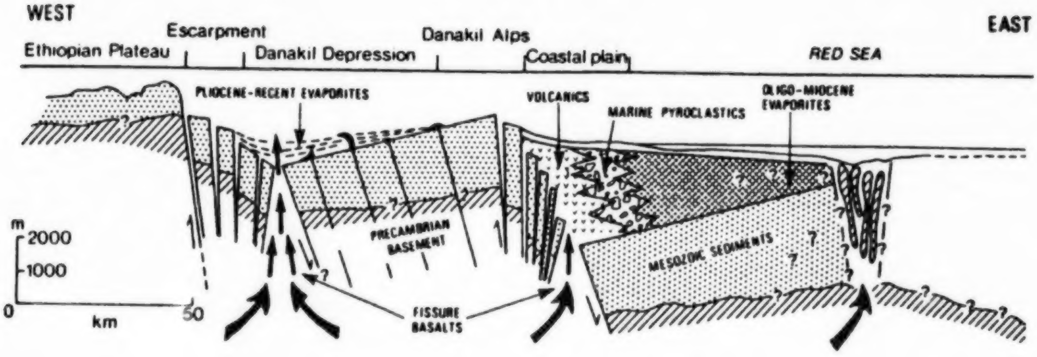

WEST
Escarpment
Ethiopian Plateau
Danakil Depression
Danakil Alps
Coastal plain
RED SEA
EAST
PLIOCENE-RECENT EVAPORITES
VOLCANICS
MARINE PYROCLASTICS
OLIGO-MIOCENE EVAPORITES
PRECAMBRIAN BASEMENT
MESOZOIC SEDIMENTS
FISSURE BASALTS
m
2000
1000
0
50
km

FIGURE 80. Section across the Red Sea and Danakil depression showing how Mesozoic sandstones and limestones, which thicken to the seaward, were block faulted and tilted landward in Tertiary times as the present Red Sea began to form. Fissure basalts formed at the intersection of horsts and graben and up to 3000 m of volcanics and volcaniclastic rocks accumulated on the flanks of the Danakil Alps. These pass laterally into marine pyroclastics and then evaporites, which are mainly halite, in the Oligo-Miocene of the eastern graben and gypsiferous in the Pliocene to Recent of the Danakil depression (after Reading 1982).

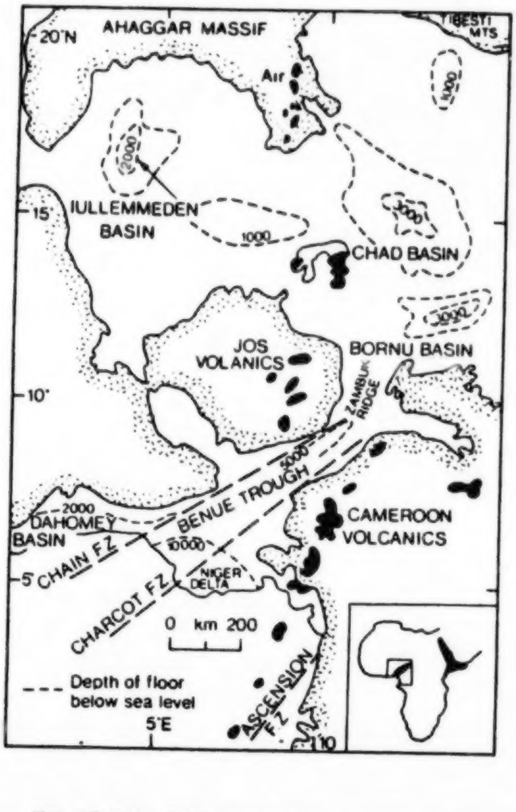

AHAGGAR MASSIF
TIBESTI MTS
20°N
Air
1000
2000
IULLEMMEDEN BASIN
15°
1000
CHAD BASIN
3000
3000
JOS VOLCANICS
BORNU BASIN
ZAMBUK RIDGE
10°
5000
BENUE TROUGH
CAMEROON VOLCANICS
2000
DAHOMEY BASIN
CHAIN FZ
10000
NIGER DELTA
5°
CHARCOT FZ
0 km 200
Depth of floor below sea level
5°E
ASCENSION FZ
10

FIGURE 81. Map of West Africa to show (1) the large gentle sag basins, such as the Chad Basin, which developed on continental crust, (2) the Benue trough, a failed rift or aulacogen of Cretaceous age, and (3) the subsequent miogeoclinal Tertiary Niger delta. Depth to basin floor in metres (after Reading 1982).

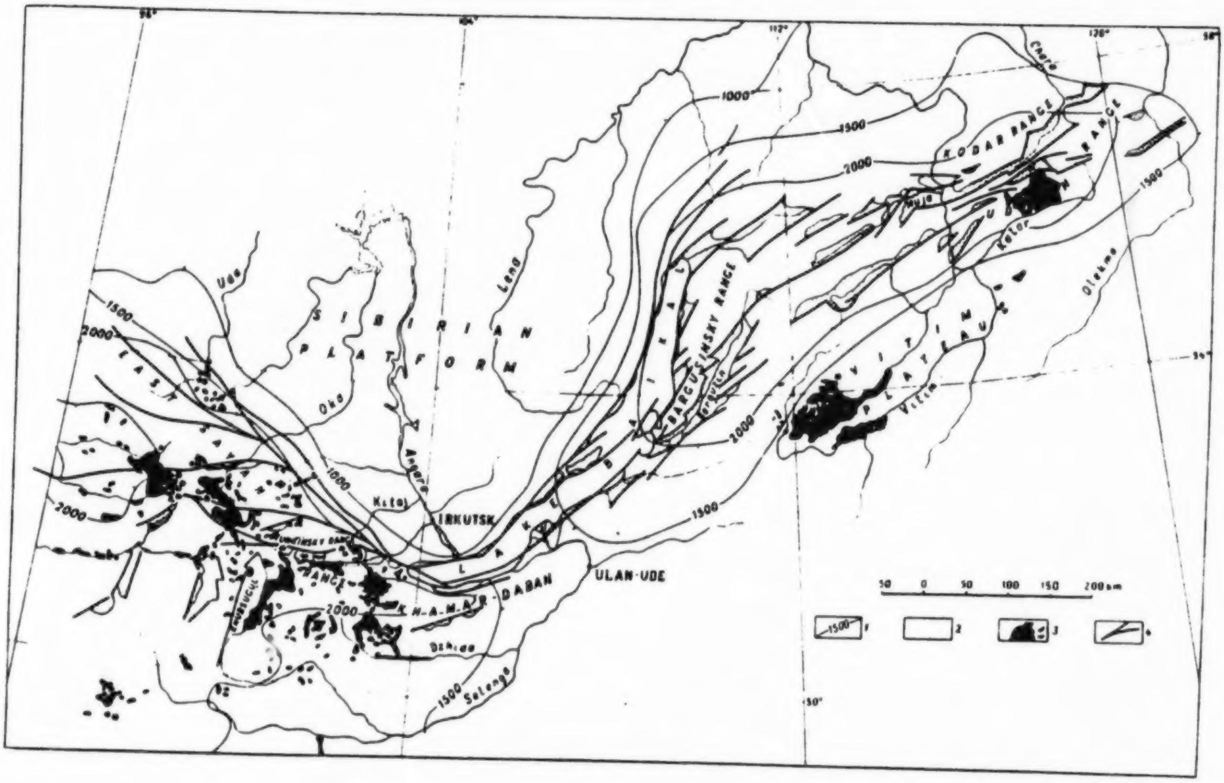

SIBIRIAN PLATFORM
EAST SAYAN
Uda
Oka
Lena
Angara
Kitoi
IRKUTSK
LAKE BAIKAL
ULAN-UDE
KHAMAR-DABAN
Dzhida
Selenga
BARGUSINSKY RANGE
KODAR RANGE
UDOKAN RANGE
VITIM PLATEAU
Vitim
Chara
Muja
Kalar
Olekma
1000
1500
2000
112°
120°
104°
96°
50°
56°
50 0 50 100 150 200 km
1500 1
2
3
4

FIGURE 82. The Baikal rift zone - an example of scattered distribution of faults, rift valleys and volcanic fields. 1 = contour lines of the Cenozoic uplift (in metres); 2 = sedimentary infill in graben; 3 = volcanic fields and centres (stars); 4 = major faults (after Logatchev 1978).

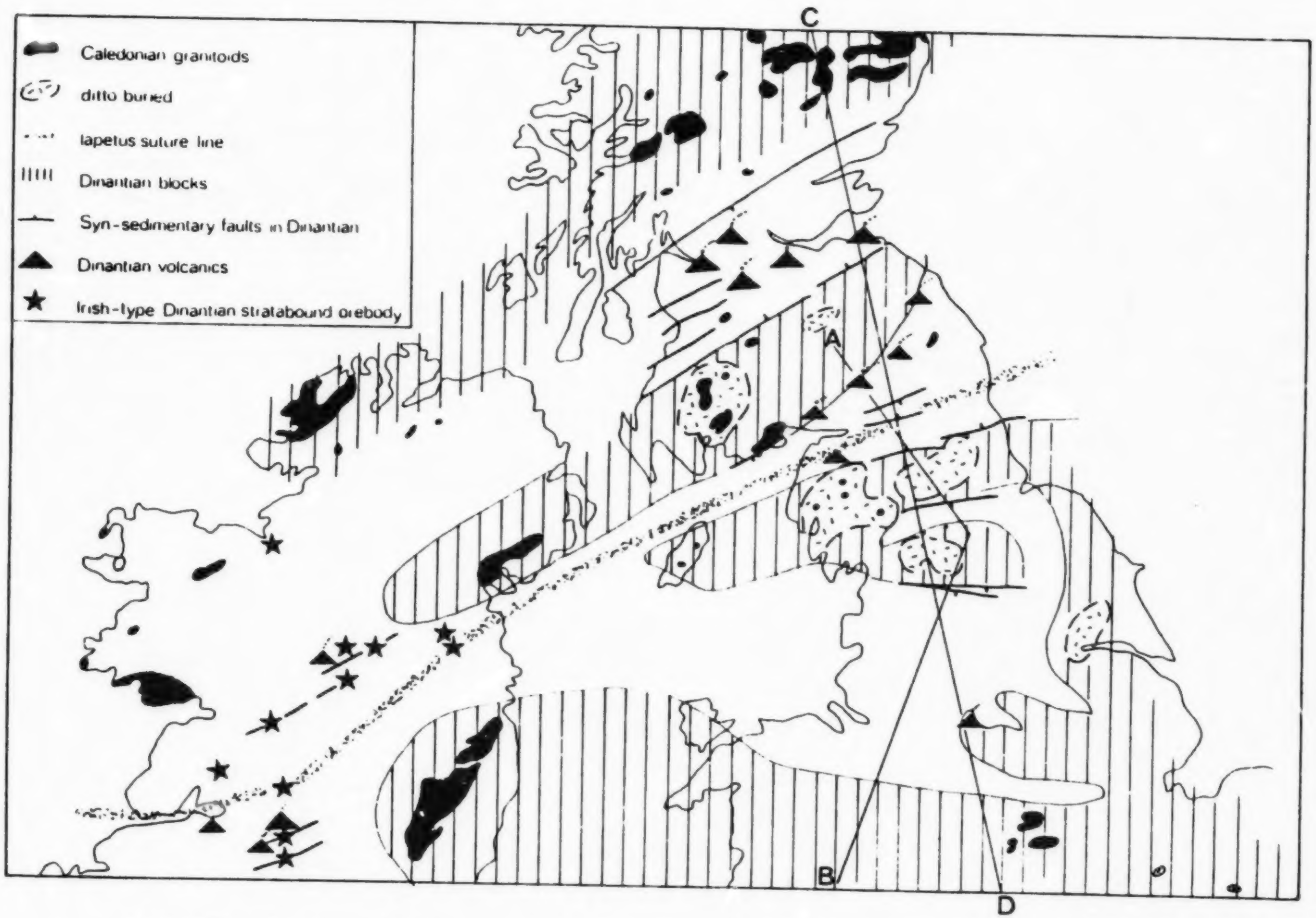

Caledonian granitoids
ditto buried
Iapetus suture line
Dinantian blocks
Syn-sedimentary faults in Dinantian
Dinantian volcanics
Irish-type Dinantian stratabound orebody
C
A
B
D

FIGURE 83. Distribution of Dinantian rift-type basins, volcanics and stratiform base metal deposits in relation to (1) Caledonian granitoid plutons; (2) Supposed line of the Iapetus suture. Section line A-B refers to Figure 84 (after Leeder 1982).

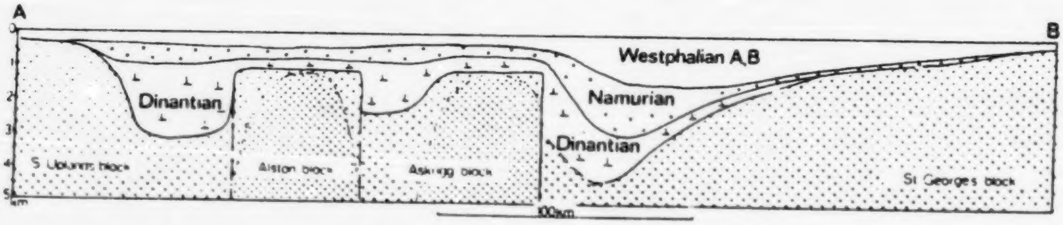

A
B
0
1
2
3
4
5
km
Westphalian A,B
Namurian
Dinantian
Dinantian
S Uplands block
Alston block
Askrigg block
St Georges block
100km

FIGURE 84. Schematic section to show the thickness of Dinantian, Namurian and Westphalian A/B successions along the line A-B in Figure 83. Note the change from numerous "rift" basins in the Dinantian to a single "sag" basin in the Namurian-Westplanian (after Leeder 1982).

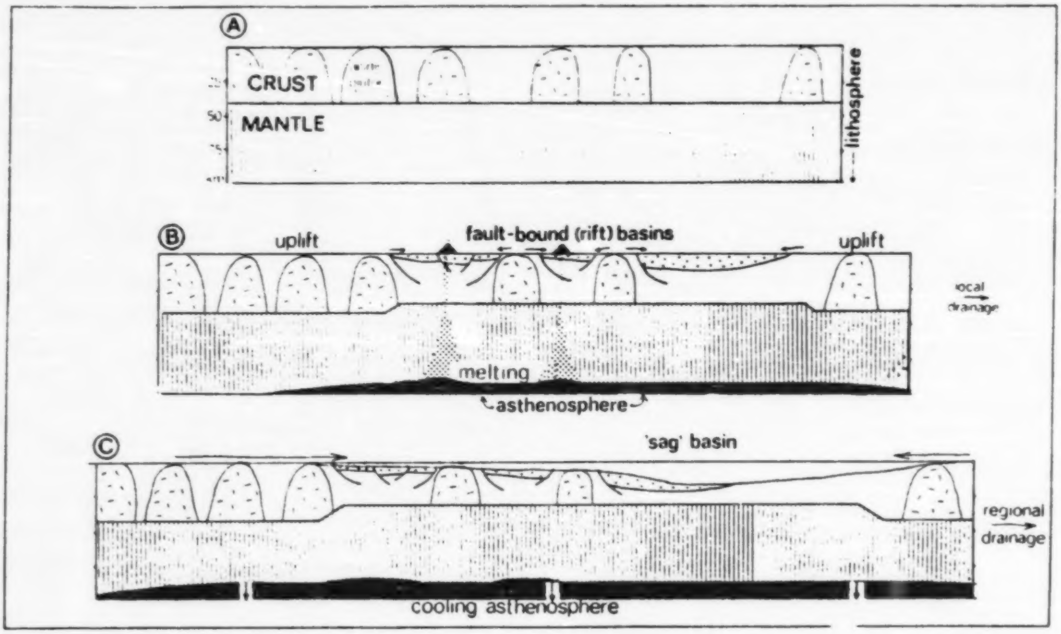

Ⓐ
CRUST
MANTLE
50
75
lithosphere
Ⓑ
uplift
fault-bound (rift) basins
uplift
local drainage
melting
asthenosphere
Ⓒ
'sag' basin
regional drainage
cooling asthenosphere

FIGURE 85. Schematic diagrams to show how "stretching" model of basin formation may be applied to explain features of the Carboniferous basin evolution and volcanism of North Britain. A = inhomogenous lithosphere with buoyant granitoid plutons in the upper crust; B = stretching phase causes tensional stress, listric faulting, crustal thinning, lithosphere thinning, high heat flow, volcanism and basin development of rift-type in areas between plutons; C = pillow of asthenosphere cools down exponentialy and causes thermally-induced, sag-type subsidence over the former rift province. Marginal uplift may occur during late phase B, as noted in the text. NB: no account is taken in C of Hercynian crustal shortening, which may have reduced the marked and exaggerated crustal thinning as indicated on the section (after Leeder 1982).

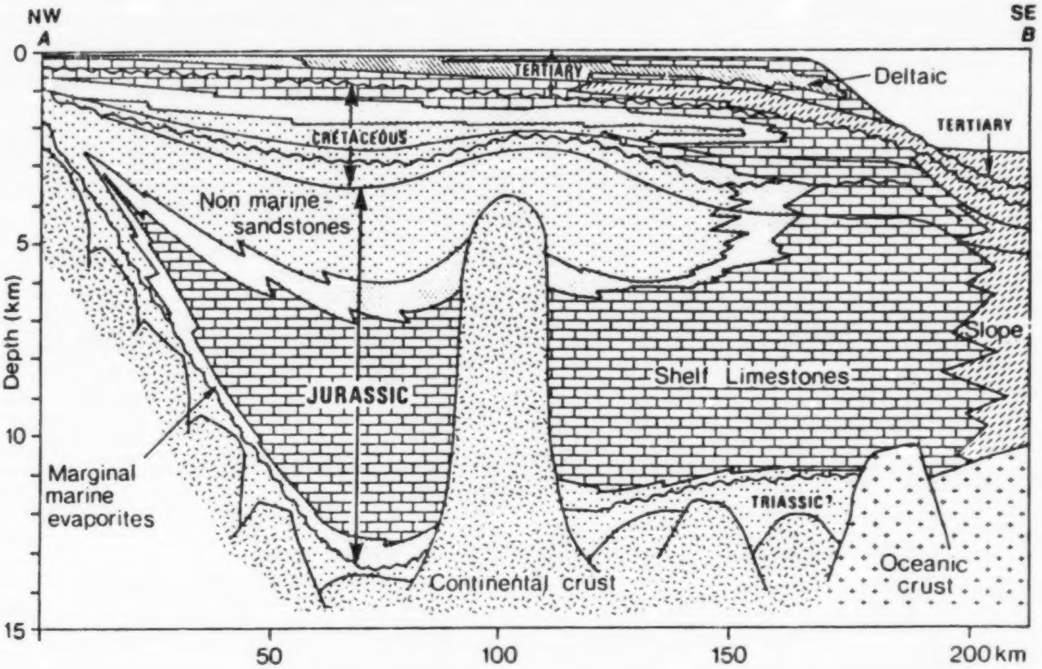
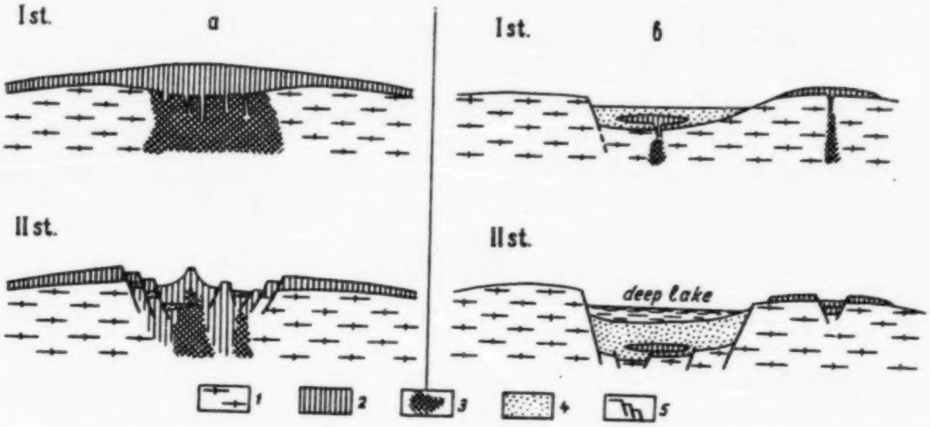

NW
A
SE
B
TERTIARY
Deltaic
TERTIARY
CRETACEOUS
Non marine sandstones
JURASSIC
Shelf Limestones
Slope
Marginal marine evaporites
TRIASSIC?
Continental crust
Oceanic crust
Depth (km)
0
5
10
15
50
100
150
200 km

FIGURE 86. Schematic cross section through the Baltimore Canyon trough which underlies the present coastal plain, continental shelf and upper continental slope off the eastern United States. The trough is about 500 km long, parallel with the present shoreline, and 100 to 200 km wide, with up to 14 km of mainly Mesozoic sediments. Triassic continental rift-valley sandstones are followed by partially synchronous marginal marine evaporites and then very thick transgressive Jurassic shelf limestones with carbonate reef build-ups over highs. Shoreward there is passage into marginal marine sandstones. A major early Cretaceous prograding wedge is followed by a late Cretaceous transgression. The Tertiary configuration is one of delta progradation with minor transgression, passing seaward into slope deposits of uncertain age and thickness (after Reading 1982).



I st.
a
I st.
б
II st.
II st.
deep lake
1
2
3
4
5

FIGURE 87. Schematic illustration of the two-stage history of rift zones with strong volcanism (a), and weak volcanism (b). 1 = sialic crustal rocks; 2 = volcanics, mainly basalts; 3 = zones of attenuation and permeability for the upper mantle melts; 4 = sediments of various origins; 5 = faults (after Logatchev 1978).

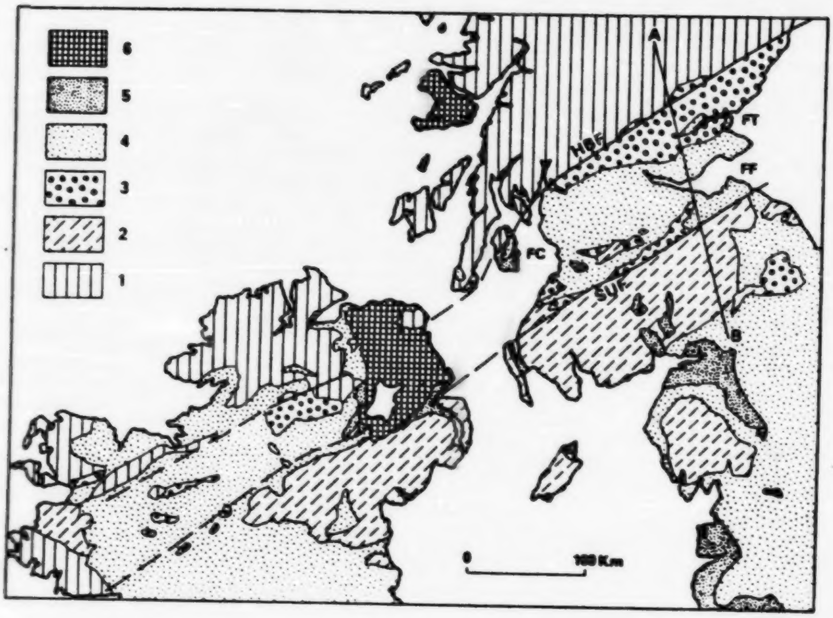


FIGURE 88a. Geological sketch map of the Midland Valley Graben. 1 = Dalradian and older; 2 = Ordovician and Silurian; 3 = Early Devonian (L.ORS); 4 = Late Devonian (U.ORS) and Carboniferous; 5 = Mainly Permian; 6 = Mesozoic and Tertiary. HBF = Highland Boundary Fault; SUF = Southern Uplands Fault; FC = Firth of Clyde; FF = Firth of Forth; FT = Firth of Tay. A-B see Figure 88b (after Francis 1978).

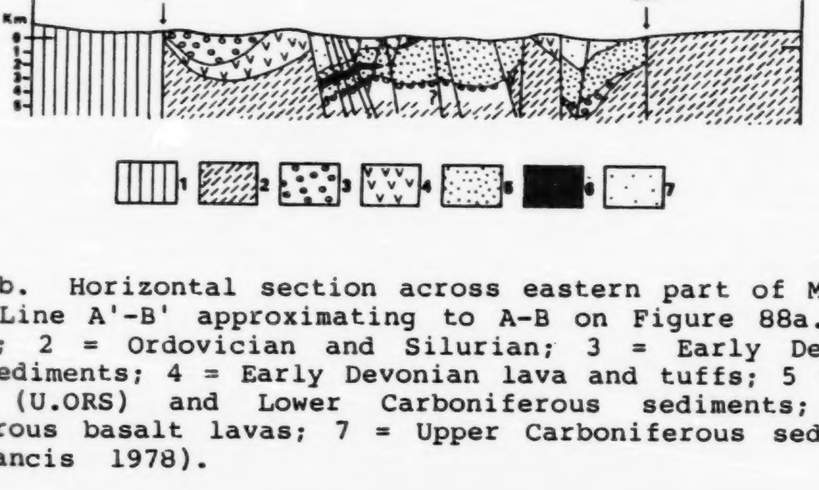


FIGURE 88b. Horizontal section across eastern part of Midland Valley. Line A'-B' approximating to A-B on Figure 88a. 1 = Dalradian; 2 = Ordovician and Silurian; 3 = Early Devonian (L.ORS) sediments; 4 = Early Devonian lava and tuffs; 5 = Late Devonian (U.ORS) and Lower Carboniferous sediments; 6 = Carboniferous basalt lavas; 7 = Upper Carboniferous sediments (after Francis 1978).

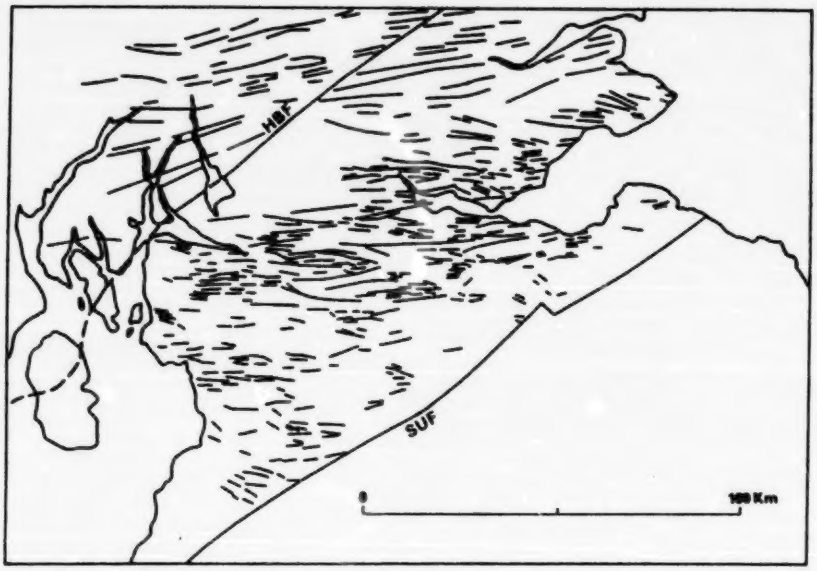


FIGURE 89a. Late Carboniferous east-west fractures associated with emplacement of tholeiite dykes. The apparently large number of fractures in the Carboniferous basins reflects the volume of structural detail provided by mining for coal and oil-shale (after Francis 1978).

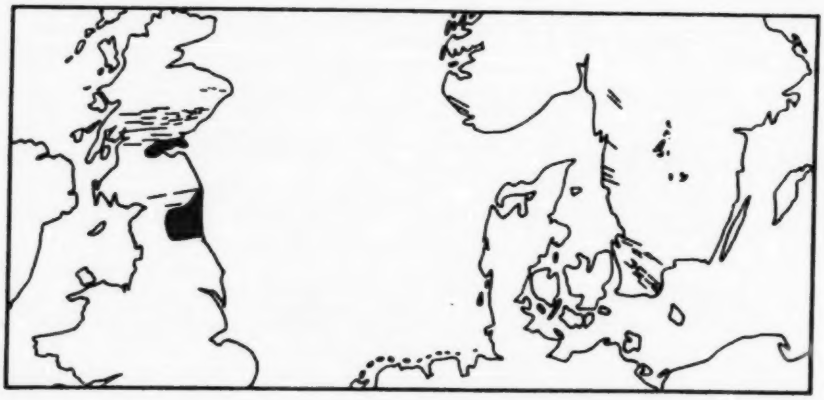


FIGURE 89b. Tholeiite dykes and related quartz-dolerite sills in northern Britain and Scandinavia (after Francis 1978).

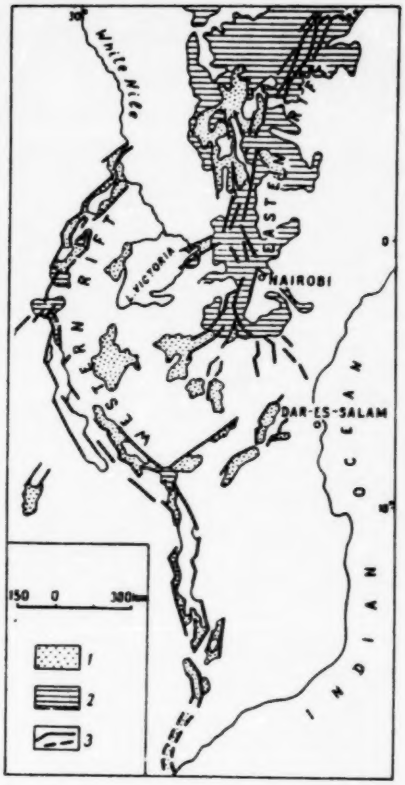
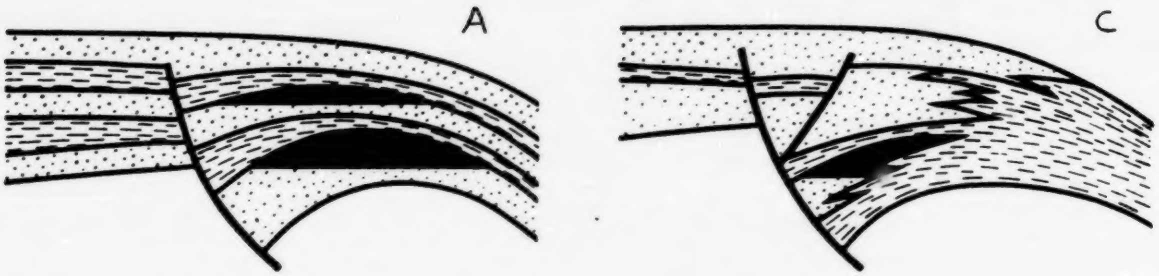
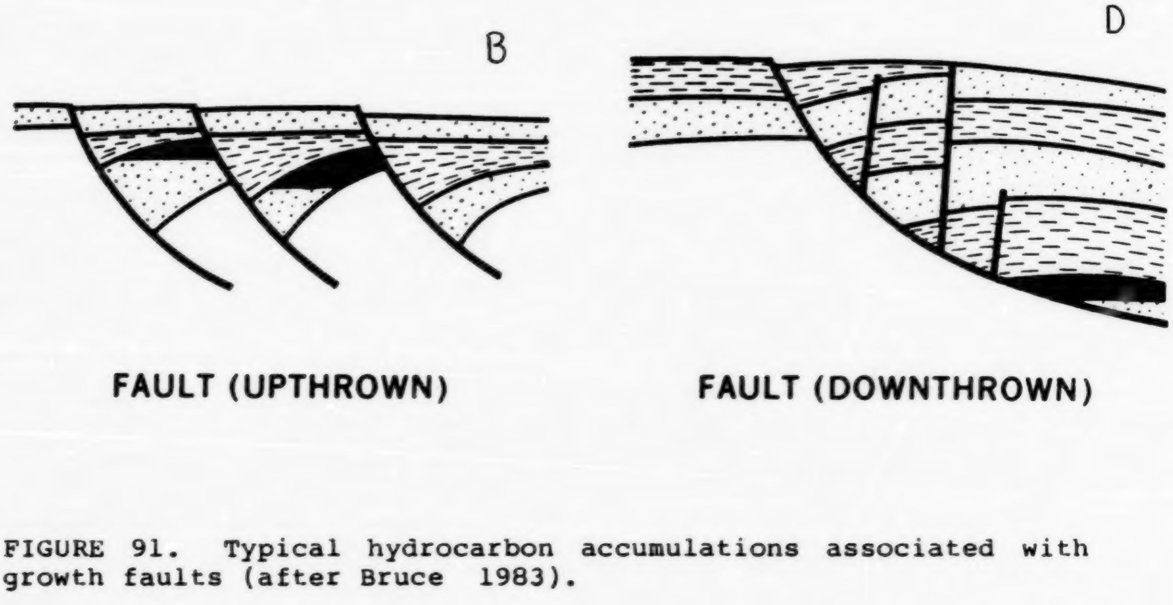

30°
White Nile
WESTERN RIFT
EASTERN RIFT
VICTORIA
NAIROBI
DAR-ES-SALAM
0
10°
INDIAN OCEAN
150 0 300km
1
2
3

FIGURE 90. Southern part of the Afro-Arabian rift system characterized by concentrated linear or belt-like groupings of major faults, rift valleys and volcanic provinces. 1 = rift valleys and depressions; 2 = volcanics; 3 = major faults (after Logatchev 1978).



ANTICLINAL (DOWNTHROWN)

COMBINATION
STRUCTURAL - STRATIGRAPHIC



FAULT (UPTHROWN)

FAULT (DOWNTHROWN)

FIGURE 91. Typical hydrocarbon accumulations associated with growth faults (after Bruce 1983).

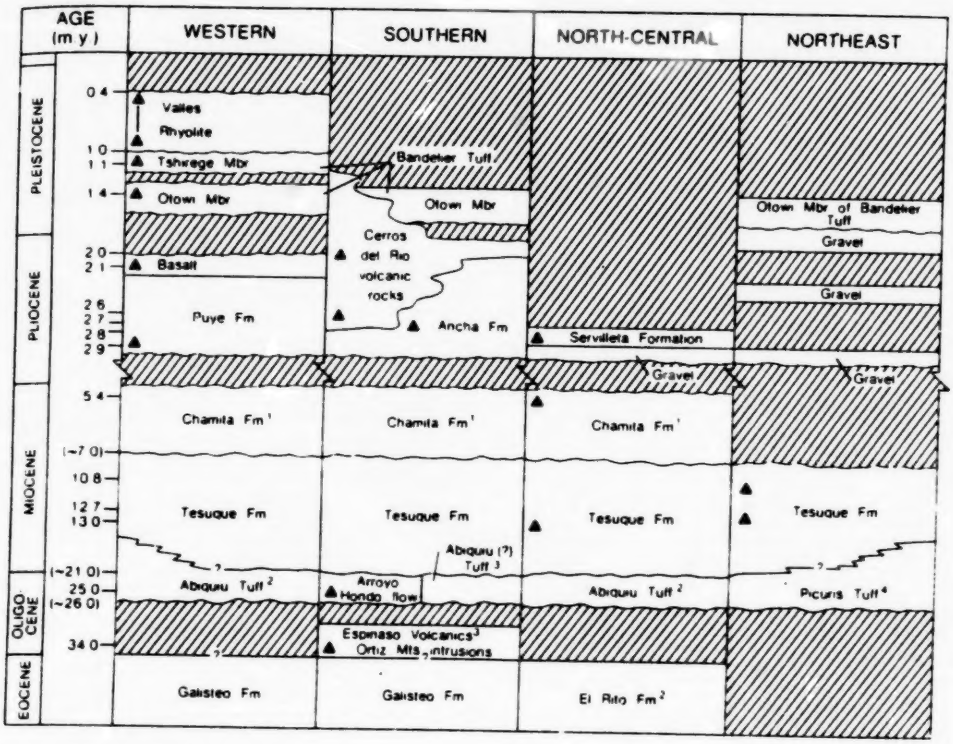


FIGURE 92. Stratigraphic correlation chart for the Espanola basin, New Mexico. Radiometric age indicated by solid triangle (after Manley 1979).